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ABSTRACT

Exploratorium Magazine communicates ideas that exhibits cannot easily demonstrate, extending the museum beyond its physical walls. This issue takes an in-depth look at the science and history of paper. Topics include: (1) Fascinating Facts about Paper; (2) A Closer Look at the Paper in This Magazine; (3) Handmade Paper; (4) Paper Airplanes; (5) The Story of Paper; and (6) Exploring Origami. (CCM)

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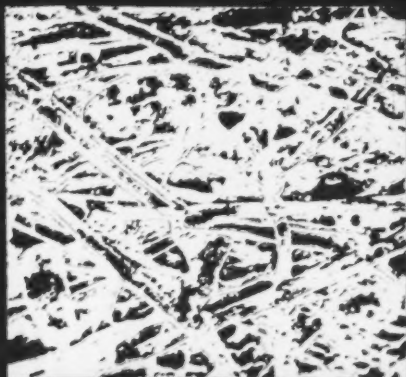
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A micrograph of photocopy paper from the collection of the Institute of Paper Science and Technology.

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Vol. 23, No. 2, Summer 1999

The *Exploratorium Magazine* is produced by the Exploratorium, a museum of science, art, and human perception. The magazine communicates ideas that exhibits can't easily demonstrate, extending the museum beyond its physical walls. Each issue takes an in-depth look at a single topic, explaining the underlying science of the everyday world.

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From the Director

Dear Friends,

Paper can be ephemeral or long lasting, depending on how it's treated over time. A building, too, is subject to forces that affect its longevity. But unlike paper, buildings can be renovated to remain useful and dynamic.

The Palace of Fine Arts, which houses the Exploratorium, is a structure that was intended to be temporary but has had a long and rich history. Once part of the 1915 Panama-Pacific International Exposition, the Palace has also housed eighteen lighted tennis courts, held jeeps and trucks during World War II, and was home to a motor pool when the United Nations was located in San Francisco. In addition, the building has served as a city Park Department warehouse, a telephone book distribution center, a flag and tent storage depot, and a temporary Fire Department headquarters. Since 1969, the Exploratorium has been proud to call the Palace of Fine Arts our home.

For thirty years, we have made relatively few improvements to our home. Only recently have we begun to renovate the building's wiring to bring state-of-the-art communications to the museum. We've also upgraded visitor amenities.

With the utmost respect for the building's history and beauty, we are poised to make some major improvements to the physical structure of the museum. Guided by the talents of the architectural firm Esherick Homsey Dodge & Davis, our current plans are as follows:

- To develop a new front entrance and entrance plaza for the Exploratorium at the center of the west side of the Palace building, utilizing the existing monumental entrance doors.
- To create an Exhibit Garden, also on the west side, to house interactive Exploratorium exhibits that take advantage of the museum's natural setting.
- To build a skylit lobby/atrium space in the museum on the axis between the new west entry and the Rotunda, providing public circulation from the lagoon and Rotunda areas on the east to the new plaza and landscaped areas on the west.

These changes will require further analysis and input. Still, we expect the renovations to be an exciting phase for the Exploratorium that will pay tribute to the natural beauty of our home, and will further the Exploratorium's mission to create a culture of learning through innovative environments. Most importantly, the renovations will ensure that the Palace of Fine Arts remains a beautiful and exciting place to visit for years to come.

Yours,

Goëry Delacôte
Executive Director

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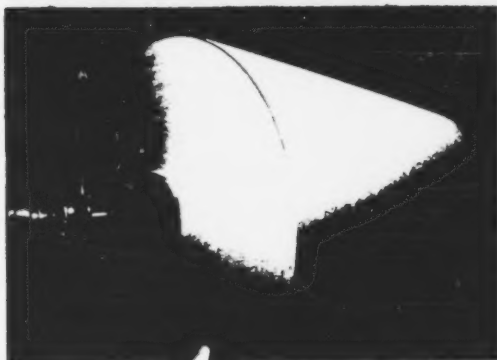


BE CAREFUL! The experiments in this publication were designed with safety and success in mind. But even the simplest activity or the most common materials can be harmful when mishandled or misused. Use common sense whenever you're exploring or experimenting.

Wondering why there are
two different types of
paper in this magazine?
See page 26.

Exploring Paper

Exploratorium Magazine
Summer 1999

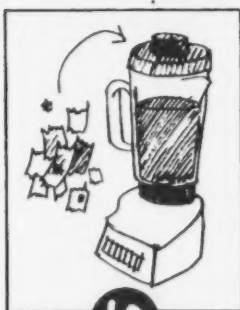


4

Pulp Nonfiction: The Story of Paper

by Jolie Velazquez

Learn about paper's mysterious
past, and trace its journey
across continents.



10

Try This!

Handmade Paper

by Karen Mendelow

Dig through your recycling bin, then turn
your trash into paper treasures.



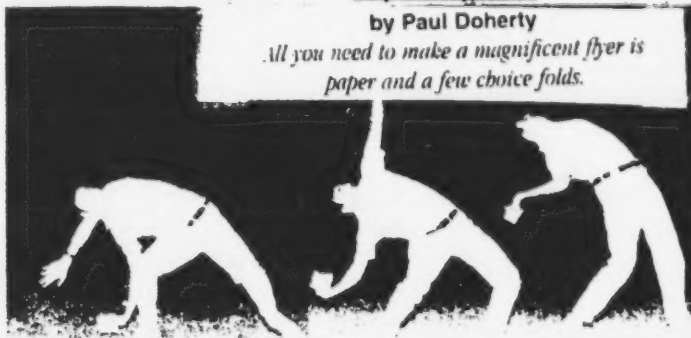
16

Try This!

Paper Airplanes

by Paul Doherty

All you need to make a magnificent flyer is
paper and a few choice folds.



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4

12

Paper in Peril!

by Ellen Klages

A pack rat reveals how to
protect paper ephemera from
its worst enemies.

Try This!

Paper's Moment in the Sun



20

Exploring Origami

by Dana Mackenzie

Learn how new materials, new methods,
and new ideas are transforming
traditional origami.

Try This!

Flapping Bird

2

First Word

Untitled, Undone

18

Fascinating facts about paper

25

All about chameleons, plus what
we'll look like in the future

26

A closer look at the paper in this
magazine

28

Tools and Toys
Exploratorium Supporters
Related Reading

29

Credits & Acknowledgments

First Word

by R. H. W. Burton

Let the paper speak to you," she said.

This blank white flat thing? What could it say?

I slumped back in my chair and regarded the bare page before me. Pale and pristine, not a mark on it, it mocked me, teased me with its endless potential. It was nothing, but I could make it into anything: the Great American Novel, a shopping list, a love letter, my will. Does a will count for Creative Writing? I was dead.

"Okay," the teacher was saying. "You have one hour. Remember, your essay must be clearly written, with an introduction, an expository section, and a conclusion that actually concludes, please. Pick any subject you like. Please begin."

All around me, people were putting pen to paper. Heads bent down, elbows shot out. In a moment I was surrounded by rhythmic scritch-scratching. I should be scritch-scratching too, I thought. Instead, I gazed around the room and accidentally caught my teacher's eye. Bad plan.

I put my head down and stared at the empty page, pen poised, just in case it said something to me. Not a word.

Okay. Well, show me pictures, then. Let me see the lives of kings and queens, the rise and fall of civilizations, the ebb and flow of time. I looked deep into the paper's soul. All I could see were little blue fibers stuck in the weave, and a strange sort of pressed-in waffle design I hadn't noticed before.

I ran my fingertips over the tiny squares in the pattern, feeling the subtle bumps and ridges and thinking how (if the paper had been speaking to me, as it should have been) flowing ink would be pooling in each little pocket. I picked at one corner of the paper with a fingernail. It pulled apart, leaving little threadlike wisps sticking out. Wounded, the paper stared back at me, and I realized I'd ruined its perfect symmetry. I turned the page around on my desk, and, one at a time, picked carefully at the tip of each sharp little corner. In a moment, the page had softened, its corners rounded and dull.

That was better. Less intimidating, somehow.

Wait! Was it saying something? Was it telling me tales of sorrow and woe? Legends of joy and laughter? Was it speaking of poets and prophets and battles of old? Hello?

I stretched back in my chair and glanced at the clock. Twenty minutes to go. I flipped the page over, thinking I really should do something. Anything.

Aha! My name. The date. Maybe my teacher's name. That would be a good start.

My pen bit into the paper. I could feel it popping over each little raised edge in the paperscape. The ink, sucked into the fibers, trailed along behind, making bright blue curlicues that fuzzed softly on each side. My hand moved automatically, tracing the familiar pattern that appeared magically behind it. Underneath, I wrote the numbers that encoded my place in time and space. My teacher's name came next and, inspired, I added "Creative Writing 101." As I dragged my pen across the paper, I could hear it whispering to me. Finally, it was speaking! Suddenly, I knew what to do.

"Thank you, everyone," the teacher was saying. "Please leave your papers on my desk on your way out the door. See you all on Friday."

Not now! Not now! My head banged down on the desk. People were filing by me, papers in hand. I sighed. Defeated by a silent sheet of paper, I crumpled the offending page in one hand, and tossed it in the recycling bin. ●

Untitled

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ed; Undone

PULP

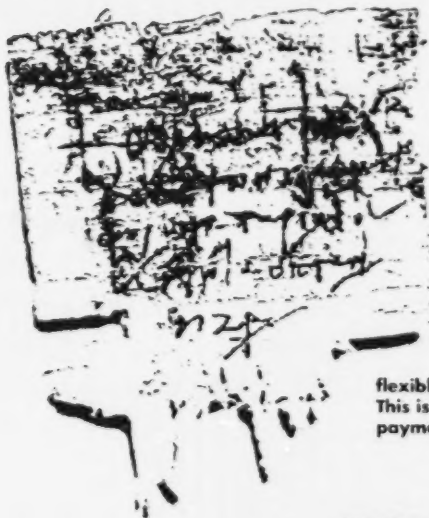
NONFICTION

THE STORY OF PAPER

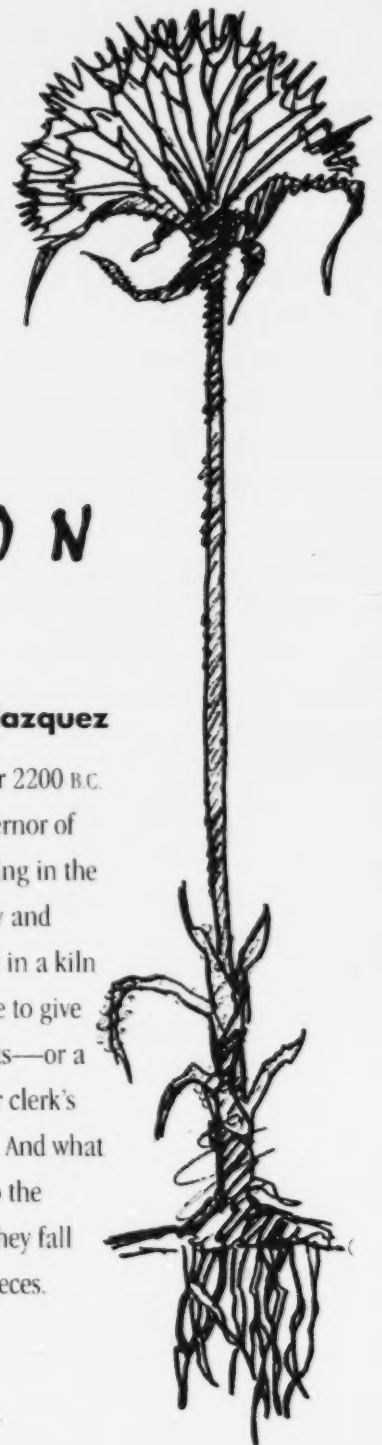
by Jolie Velazquez

Imagine that you are living in the Tigris-Euphrates Valley in the year 2200 B.C.—long before the advent of paper. You work for the satrap, the governor of your province, as the tax collector, and you need to tell a subject living in the next village that his taxes are past due. You pick up a tile of wet clay and scratch the amount owed into the surface with a sharp stick, bake it in a kiln to harden it, and give it to your clerk to deliver. But what if you have to give

the same notice to a hundred subjects—or a thousand! At some point, either your clerk's back (or his donkey's) will give out. And what about that pile of tiles stacked up to the ceiling in your office? Sometimes they fall and break into annoying puzzle pieces.



Before the invention of paper made from a pulp, papyrus was used to write on because it held pigment, was flexible, and could be rolled up and stored. This is a section of a Greek papyrus order for payment from the seventh century A.D.



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The Journey of Papermaking From China

Finding something to write on that's durable and lightweight has been a dilemma for humans ever since we took our glorious invention—writing—down from cave walls and moved our messages from place to place. In our search for the perfect medium, we have used bones, shells, stones, metal plates, clay tablets, planks of wood, leaves, plant stalks, bark, ceramic tiles, animal skins, and cloth to record our words. These solutions were adequate when societies were simple, populations small, and the majority of citizens did not read because they didn't need to. But as populations increased, people needed ways to communicate, and as those people became educated and gained leisure time, there was more demand for the written word.

In the third century B.C., the Egyptians solved the problem with *papyrus*, the material from which we get our word *paper*. Although the origins of papyrus's development as a writing material are a mystery, the water reed *Cyperus papyrus* grows along the Nile delta, so it was readily accessible. Papyrus is made from thin slices of the reed's stalk that are pounded and glued together to form long sheets. When the sheets are dry, papyrus takes pigment that doesn't run. Also, papyrus retains its flexibility so that it can be rolled up for convenient storage. The Egyptians created vast libraries (such as the one in Alexandria, which was probably destroyed in a

series of Roman sieges around 40 B.C.) containing information about their own history and science, and that of other cultures. Papyrus worked well for the Egyptians, but it was not an adequate solution for their neighbors. The great drawback was that papyrus grew in very few locations and the Pharaoh's subjects were forbidden to export it.

Around 200 B.C., one of the Pharaoh's disgruntled neighbors, the king of Pergamum, decided to use sheepskin in place of papyrus. His craftspeople cleaned, split, stretched, and treated hides with lime to ensure softness. Called *parchment*, this material became the most

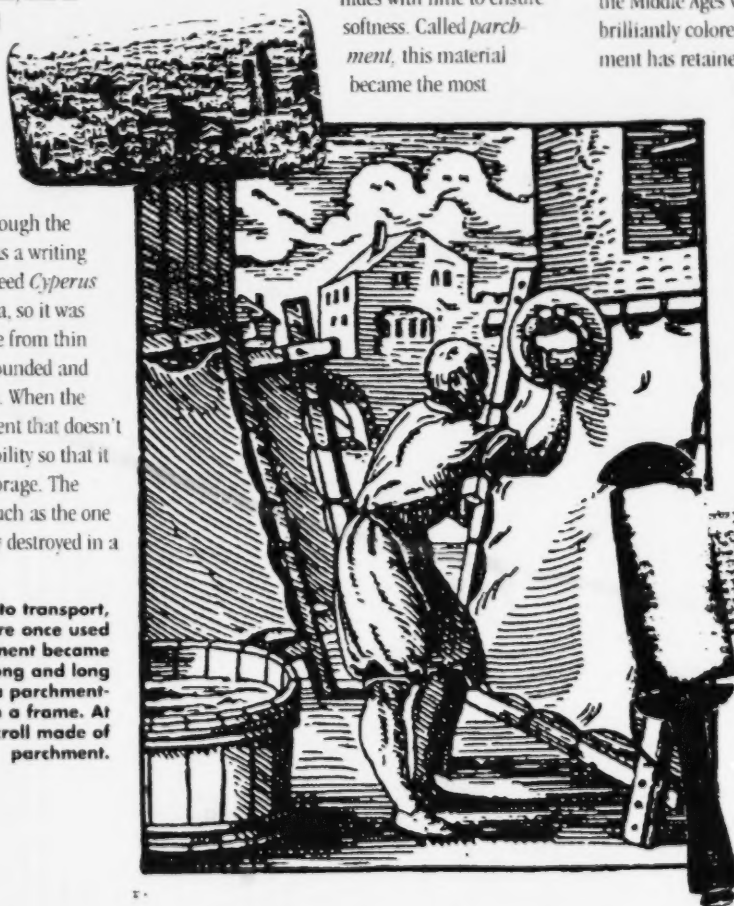
commonly used writing medium in the Western world, especially in Europe, until the fifteenth century.

Parchment and its cousin *vellum* (calfskin or goatskin) were expensive to produce and, because the supply was always small. Only highly skilled or wealthy writers could use them. Still, these materials are strong and long lasting. Illuminated manuscripts created by monks in the Middle Ages were made of vellum and are brilliantly colored and legible even today. Parchment has retained its status and is still used for highly prized documents, such as diplomas and commendations.

IT'S THE PULP! —PAPER AS WE KNOW IT

Although people experimented with writing on an amazing variety of materials, "true paper" (paper made from a pulp) was invented in China,

Though heavy and difficult to transport, clay tablets (center left) were once used to write on. Later, parchment became popular because it was strong and long lasting. In the woodcut, a parchment-maker scrapes skin held in a frame. At bottom right is a Hebrew scroll made of parchment.



where bamboo strips and silk cloth had proven inadequate for the application of thin inks. In A.D. 105, a court official named Ts'ai Lun reported to his emperor that he had found a new writing medium (see sidebar, "Ts'ai Lun: The Legendary Inventor of Paper" on page 7).

The ingenuity of Ts'ai Lun's papermaking method lies in the way it can be adapted to many kinds of raw materials. Papermakers devised many methods of steeping plant or cloth fibers, bleaching them with alkaline substances to remove pigments, sometimes seasoning the pulp for a period of time in heated tubs, and cleaning the resulting mash to remove unwanted particles. A craftsperson dipped a wooden frame lined with a cloth or wire screen into the pulp to create a thin layer on the screen. When the fibers set,



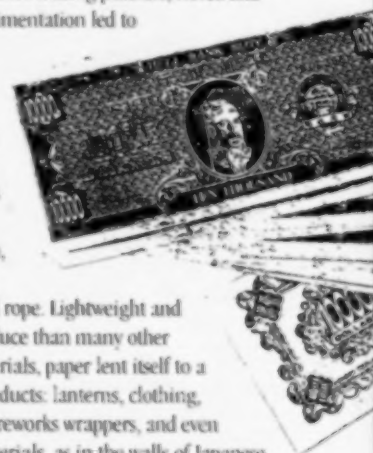
All of these Chinese, Tibetan, and Mongolian manuscripts were written on soft, absorbent paper made from the inner bark of the mulberry—with one exception. The black, Siamese manuscript paper is made out of khoei bark, stained with a betel palm nut pigment.

the sheet was pulled free from the screen ("couched") and dried. Originally, the sheets were simply placed over racks to dry, but later craftspeople learned that by placing the sheets between wool blotters in giant presses, they could squeeze excess water from the sheets and help flatten the surfaces. To make the surface less permeable to thin inks, papermakers used a technique called *sizing*: they dipped the sheets in gelatinous substances, which filled in the tiny ruts, smoothing the texture and leaving the paper less porous.

China enjoyed a virtual monopoly on paper

for five hundred years, partly due to China's isolation and partly because of its wish to retain the technical secret. But eventually, papermaking spread to China's trading partners, Korea and Japan. Experimentation led to the use of different kinds of materials to make paper pulp, such as mulberry leaves, rattan, rice straw, seaweed, and rope. Lightweight and faster to produce than many other natural materials, paper lent itself to a variety of products: lanterns, clothing, umbrellas, fireworks wrappers, and even building materials, as in the walls of Japanese homes. Asian papermakers experimented with applying substances such as gypsum, ground lichen, or flour starch to the paper's surface to make it smoother, brighter, and less permeable to ink, or lacquer to make it stronger. We can thank China for initiating the use of toilet paper, as cited by a Persian visitor who observed this hygienic innovation in 875.

The Chinese were also the first to use paper as currency. The ancient custom of placing coins in the graves of loved ones encouraged thieves, but when paper became readily available, grieving relatives painted coin replicas on paper, and buried those representations instead. Eventually all kinds of funerary offerings were made of paper: animals, foods, tools—almost any item that one could wish to take into the next life. The practice continues today with the burning of



In this woodblock by the renowned Japanese artist Hokusai (1760–1849), women beat bark as part of the papermaking process. Note the three wooden boards with paper drying on them in the background.

Modern "spirit money," a funerary offering, is still available in Asian communities (above center).



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"spirit money" at ceremonies for the dead. Court officials in the Tang Dynasty thought that paper money was a brilliant solution to the problem of transporting heavy coins and, in the year 660, began printing official paper currency.

THE SECRET REVEALED

Until the mid-700s, true paper was made only in the East. Paper began to make its way westward when the Arabs wrested the secret of papermaking from the Chinese. Following a battle in Turkestan in 751, the Arab victors forced Chinese prisoners to reveal the process.

By the end of the eighth century, papermaking was a prosperous trade in Samarkand (now in Uzbekistan), the easternmost trading center of Islamic influence. By the tenth century, the skill passed to other commercial centers in Damascus, Baghdad, Cairo, and Marrakech. When they were unable to obtain Chinese silk or plant fibers, the Arabs began to use linen rags—cloth made from the flax plant—for their pulp. By 1035, paper was so readily available in the Middle East that food sellers used it to wrap purchases. Back in China around this time, scavengers made forays to collect used or scrap paper items to resell to the mills, the first example of post-production recycling in the industry.

Imported paper began to appear in Europe early in the eleventh century, but the trade did not become established there until the middle of the twelfth century. Legend tells of a French Crusader, Jean Montgolfier, who served in the Holy Land during the Second Crusade. In 1147, he was taken prisoner and sentenced to serve three years in a paper mill at Damascus, where he learned the papermaking craft. When Montgolfier returned to France, he brought the secrets of papermaking with him, and the mills he established flourished for two hundred years. Archeological evidence and archival references, however, indicate that paper mills appeared in Italy and Spain at roughly the same time, so no one is quite sure where the first European paper entrepreneur might have started plying the trade.

While paper was valued in the Middle East, many Europeans distrusted it because it was both fragile and retained a "heathen" reputation.

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Exploring Paper

Ts'ai Lun

THE LEGENDARY INVENTOR OF PAPER

Ancient Chinese scholars credit Ts'ai Lun, a court official who held a variety of posts for the imperial family, with the invention of paper in A.D. 105.

Prior to that time, the Chinese wrote on strips of bamboo or pieces of silk (or other types of cloth). These materials had a number of drawbacks. Bamboo and silk were difficult to write on. The characters had to be painted on using special techniques to prevent the ink from running. Silk was very expensive, and bamboo was heavy and difficult to transport.

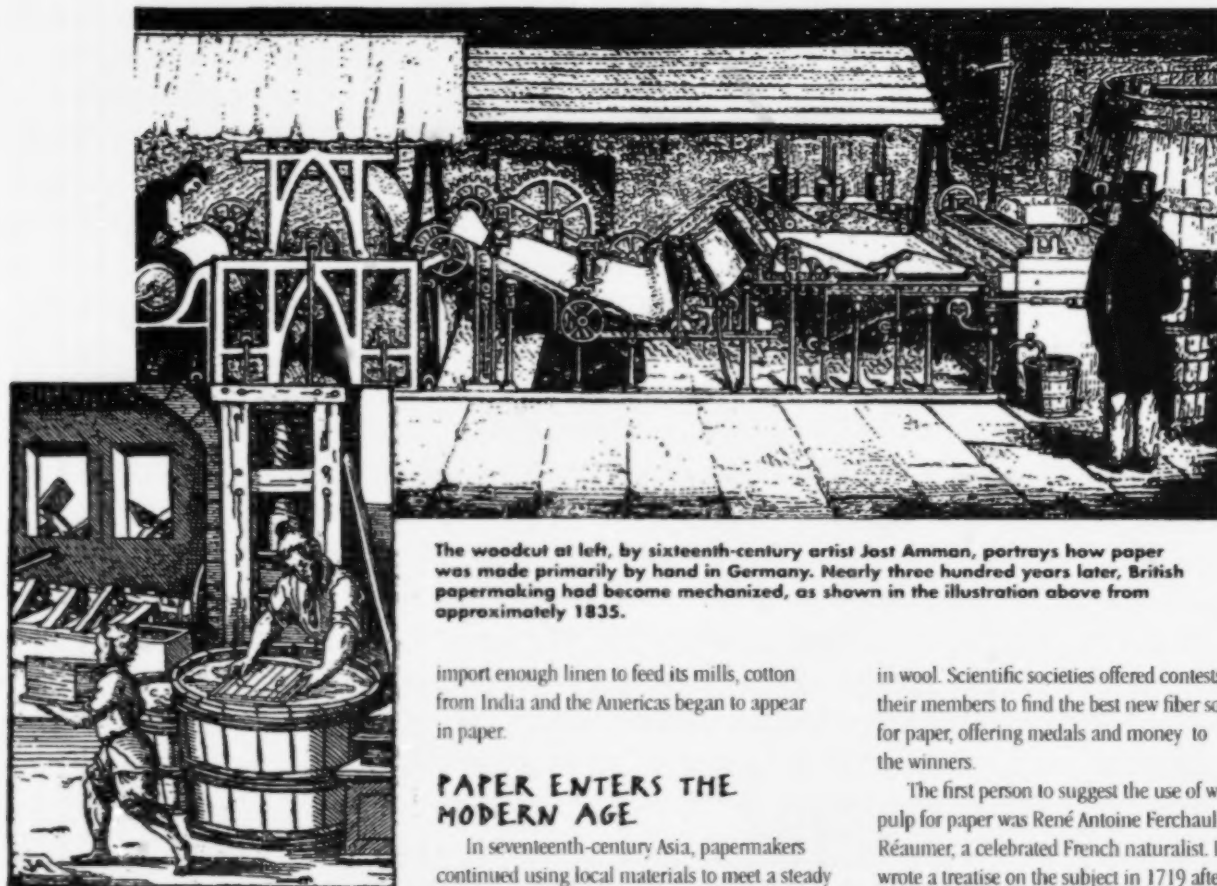
by Jim Spadaccir

According to fifth-century historian Fan Yeh, who provides most of what we know about Ts'ai Lun, "It was Ts'ai Lun who conceived the idea of making paper from the bark of trees, hemp waste, old rags, and fish nets. . . . He made a report to the Emperor, the first year of the reign of Yuan Hsing, upon his researches in papermaking, and was highly commended upon his competency." Ts'ai Lun's method included mashing materials into a wet pulp, then spreading the pulp onto a screen to dry in a continuous piece. The result was a superior surface on which to apply the beautiful brushed calligraphy developed after Mêng T'ien invented the camel's hair brush in 250 B.C.

Some modern scholars question whether Ts'ai Lun was the actual inventor of paper or just the patron of the invention. We do know, however, that he and his apprentice Tso Tzu-yi made improvements to the papermaking process, such as smoothing the paper surface with agate stones and drying the sheets on plaster surfaces.

Ts'ai Lun was well rewarded by the imperial family, who understood that paper was an invention of the greatest significance. But its monumental contribution to human culture can be fully appreciated only as we look back through time. Historian Michael H. Hart, in his book *The 100: A Ranking of the Most Influential Persons in History* lists Ts'ai Lun as number seven (just ahead of Gutenberg, the inventor of moveable type). Hart argues that paper helped China achieve the most advanced civilization on earth.

A household name in China, Ts'ai Lun is deserving of greater recognition in the West.



The woodcut at left, by sixteenth-century artist Jost Amman, portrays how paper was made primarily by hand in Germany. Nearly three hundred years later, British papermaking had become mechanized, as shown in the illustration above from approximately 1835.

coming from Islamic countries. The Church banned its use for religious texts, and governments would not recognize legal documents written on it. Paper also threatened the income of livestock owners who supplied the skins for parchment and vellum. The invention of the printing press in the mid-1400s, however, led to a burgeoning literate public and created a substantial demand for the hitherto suspect material. Eventually, paper centers in Valencia, Fabriano, Cologne, Mainz, Nuremberg, and Amsterdam proved that they could supply the paper needed for the busy printing presses.

Demand and technical innovation went hand in hand. Better and faster ways of making paper were developed that included larger tubs, molds, and presses; better heating methods and improved stirring devices for the pulp; rollers to smooth, fans to dry, and various techniques to treat and size the sheets. In order to use water-wheels to move the powerful new machinery, papermakers built their mills next to streams and rivers. Like the Arabs, Europeans initially used linen fibers in their paper pulp. When it became clear that Europe could not grow or

import enough linen to feed its mills, cotton from India and the Americas began to appear in paper.

PAPER ENTERS THE MODERN AGE

In seventeenth-century Asia, papermakers continued using local materials to meet a steady market. But European growth, both in its own population and in its colonization of other countries, led to the introduction of bureaucratic and communication systems that required vast quantities of paper, and created an ever-increasing reading public.

The American colonists encouraged literacy and education very early on, and they didn't like paying import taxes on paper coming from England. William Rittenhouse and a group of Germantown, Pennsylvania, investors built the first paper mill in America in 1690. The Ivy Mill in Chester, Pennsylvania, built shortly afterwards, supplied Benjamin Franklin with the material for his news journal and trained craftspeople for a rapidly expanding American trade.

By the mid-eighteenth century, papermakers and printers began to realize that linen and cotton could not provide the tremendous amount of fibers needed in a print-hungry culture. The proliferation of paper cartridges for firearms used in almost continuous wars also added to the demand. Advertisements appeared admonishing people to save rags; ladies were advised to offer up their old cotton or linen handkerchiefs and petticoats for sale to the paper mills; and English law decreed that loved ones could only be buried

in wool. Scientific societies offered contests to their members to find the best new fiber sources for paper, offering medals and money to the winners.

The first person to suggest the use of wood pulp for paper was René Antoine Ferchault de Réaumur, a celebrated French naturalist. He wrote a treatise on the subject in 1719 after observing wasps creating their nests with digested wood. Wood might seem an unlikely raw material for papermaking, but dry wood is about half cellulose, the fibrous plant substance that's the main ingredient of paper. The trick is to follow the wasps' lead and *pulp* the wood—separating the cellulose fibers by physically grinding them apart or by processing them chemically.

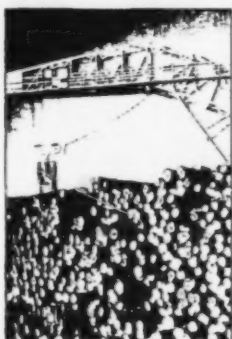
De Réaumur did not try to make wood paper himself but left it to Thomas Greaves and Mattias Koops in England to put his theory into operation. Greaves created the first successful examples of wood paper in 1787, winning an industrial contest sponsored by the Society for the Encouragement of Arts, Manufacturers, and Commerce. Koops built the first mill to make wood paper. Although he failed financially, his innovations for handling and bleaching wood pulp became the basis for all future wood paper production. Unfortunately, he was just one of many technical geniuses in the story of paper who were unable to capitalize on their discoveries.

In 1798, French papermaker Nicholas-Louis Robert designed a prototype for a new continuous-sheet or roller-type papermaking machine. The

process of making paper sheets one or two at a time was labor intensive, and Robert's admitted incentive for inventing his machine was to eliminate troublesome workers from his employ. However, a financial crisis forced Robert to sell his patent, and when he was able to buy it back, it was too late to profit from it.

In England, John Dickenson heard of Robert's machine and developed a better model that was in operation by 1809. Dickenson became famous for creating a continuous-thread paper used for printing postage stamps. (In the process, a single, long silk thread was laid into the sheets before pressing, making it possible to distinguish official stamps from counterfeit ones.)

The next innovations took place in Germany. In 1840, Frederick Gottlob Keller patented his design for a wood-grinding machine that separated the fibers without breaking them up. Other grinders had turned wood into mulch, which produced very weak paper. And by 1857, brothers Benjamin and Richard Tilghman had developed a chemical method for removing a resinous



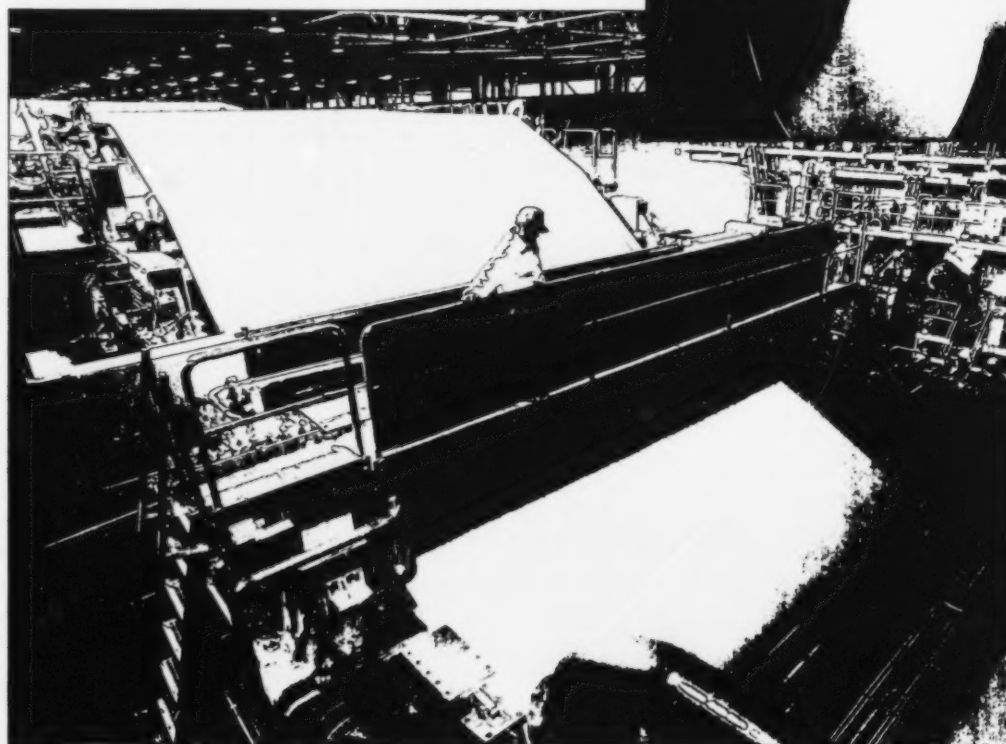
adhesive called lignin from paper pulp so that the paper would not rapidly deteriorate. This had been an annoying problem that plagued papermakers and limited wood-paper use to short-lived documents such as newspapers or advertisements. With these

improvements, wood paper became a more stable product, cheaper and more readily available for a rapidly expanding leisure-reading market. The rise of the popular novel is sometimes attributed to the use of cheap but strong paper.

Today, modern paper mills use huge machines that run on electricity, and technicians accelerate the pulping process with a variety of chemicals. But no matter what embellishments or technical improvements have been made over the centuries, Ts'ai Lun's basic process for making true paper has remained the same. The page on

which you are reading these words may not have been touched by human hands until this magazine came off the press, but it started as a pulp that passed through the same steps invented almost 1900 years ago.

In addition to print material, contemporary paper manufacturers provide many other useful items, such as product packaging and corrugated construction units for buildings. Ranchers have even used paper in cow feed. The uses of paper seem limited only by the supply of raw materials and an inventor's imagination. Fortunately, we again know how to recycle paper—for despite the promise of a "paperless" society by some computer advocates, the demand for paper continues to grow. ●



At left is the wet end of a modern papermaking machine. The pulp shoots out of a thick pipe (shown at the bottom of the photo) and forms a continuous sheet. The dry end of the process produces a roll of paper (like the one shown above) that's 40 to 60 feet long and weighs as much as 22 tons.

Handmade Paper

Papermaking is a fun project to do outside with friends on a sunny day, but it's easily done inside as well. It will take about two hours for the basic papermaking process, and you'll end up with around fifteen lovely sheets that you can use for cards, picture frames, or whatever your imagination suggests.

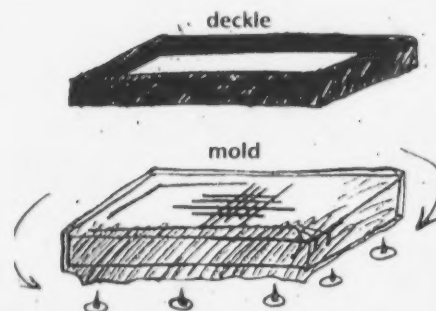
The ingredients for creating beautiful handmade paper are close at hand—just go mining in your paper recycling bin. You begin by pulverizing the waste paper. Then, after a few short steps, the fibers rejoin before your eyes to create new paper.

You'll be making 100 percent post-consumer content paper, which means that all your material has been used before—and that's really quite an achievement. Public demand for recycled paper has encouraged paper companies to retool their mills so that they can process paper that we recycle from our homes and offices. But a large percentage of recycled paper is made from *pre*-consumer material—misprints and overruns from printers, for example. Although 100 percent post-consumer content paper is available, most commercially made printing or writing grade recycled paper contains only 10 percent to 30 percent post-consumer waste.

While there are environmental costs in making recycled paper, the process has less of an ecological impact than that of making paper from raw materials. As you make your own paper, you'll observe the water and energy required to reprocess paper fiber. In commercial manufacturing, producing printing grade recycled paper can save as much as half the energy that's needed in making paper from wood pulp, and there's a savings of water as well. As you admire each beautiful and unique piece of handmade paper you've created, you will gain a first-hand understanding of the papermaking process and an appreciation of the importance of paper recycling and paper conservation.

MATERIALS

- About 50 sheets of white photocopy paper from your recycling bin
- About 12 sheets of colored photocopy paper or uncoated gift-wrap paper
- 2 wooden frames that are flat across their top surfaces (5" × 7" picture frames work well)
- A fiberglass or plastic screen (available at hardware stores)
- A staple gun or tacks
- A dishpan
- A blender
- Disposable kitchen cloths (Handiwipes, for example), 1 cloth for 2 sheets of new paper
- A sponge
- A stack of old newspapers
- Paper enhancements: food coloring, potpourri, dried flowers, dried herbs and spices, seeds, thread, lint from the dryer, etc.
- A packet of plain gelatin (needed if you're making stationery)



MAKING THE MOLD AND DECKLE

Take your two picture frames and remove the glass and backing from both. (Or make your own frames out of wood.)

To make the mold, stretch the screen tightly over the surface of one of the frames, and attach the screen to the back of the frame with a staple gun or tacks. The second frame will be used as the deckle, which makes the sheet of paper the desired size.

2. PREPARING YOUR MATERIAL

The evening before you plan to make paper, sort the paper in your recycling bin by type. Used white photocopy paper is the best material to start with for the pulp base; avoid newsprint and glossy paper. Rip the copy paper into small pieces, roughly an inch square. Soak the pieces overnight in a bucket of water.

Rip assorted sheets of colored paper into small pieces, and soak them separately. A good ratio to begin with is four times as much white paper as colored paper. Colored photocopy paper and uncoated gift-wrap paper are good choices, but glossy, brightly colored magazines can be used in small amounts for accents.

3. MAKING THE PULP

Put a handful of the soaked white paper into the blender. Add warm water to fill the blender about three-quarters full. Blend for up to a minute until the mixture has a consistency something like that of oatmeal. (If the mixture is not blending well, or if the motor is straining, add more water, or remove some paper.)

Repeat this process four times to form the batch of basic pulp.

Dump the pulp into a large, deep dishpan, and swirl the pulp around with your hands. You'll probably have to add more water at this point; the mixture should be about 90 percent liquid. (You may have noticed that it takes quite a bit of water to process the paper fiber.) Since you're always mixing the pulp with your hands, warm water helps to keep your hands from getting chilly.

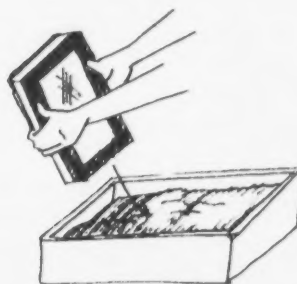
If you plan to use your paper as stationery, dissolve a packet of gelatin in hot water, and stir the gelatin into the pulp mixture. The gelatin, which is known as *size*, will make the paper less porous. Without the size, ink would bleed.

Now lightly blend your soaked colored paper for about ten seconds. Don't overblend—you want the colored paper to appear in your paper as confetti-like accents. Alternatively, you may add other materials or food coloring directly to the pulp, or you can add textures on top of the pulp after forming a sheet. For example, you might want to add some wildflower seeds on top of the paper. Cards made with seeds can later be planted by the recipients to create flower gardens.

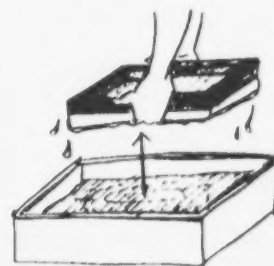


4. FORMING A SHEET OF NEW PAPER

Always stir the pulp just before dipping the mold and deckle into it. Hold the mold with the screen facing up. Place the deckle upside down on top of the mold so the smooth sides of the frames face each other.



Grasp the mold and deckle securely and lower them vertically into the dishpan.

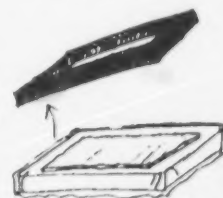


Immediately bring the mold and deckle to a horizontal position under the pulp and lift them straight up, allowing the pulp to cover the screen.

Don't let the pulp collect too thickly on the screen—thinner paper turns out better! Let the excess water drip off for about two minutes. You can rest the mold and deckle on a corner of the dishpan while the water is draining. If you want to add seeds or other adornments to the top of the paper, now is the time.

Set up a drying space where the handmade paper can be left overnight. Place one-half of a disposable kitchen cloth on top of several sheets of newspaper.

Lift off the deckle. Turn the mold over onto the cloth so that the pulp side is down. With a sponge, soak up the water from the back side of screen. Gently pat the screen to soak up the water; don't wipe it. Make sure to sponge well around the edges. Squeeze the water out of the sponge into a small container or back into the pulp pan. Keep soaking up the water until you see the paper separating from the screen. Starting at one corner, gently remove the mold.



Repeat the above process to make as many sheets of paper as you like.

Let your paper dry undisturbed overnight. When it's dry, gently peel off the kitchen cloth from each sheet of paper, starting at one corner. If a sheet isn't dry on the reverse side, turn it over and let it finish drying. When all the sheets are completely dry, stack them and place heavy books on top of the stack for a couple of days to press the sheets flat. (To speed up these last steps, you can iron partially dry paper between two kitchen cloths at a medium temperature.) After the sheets have been pressed, they'll be ready for display or to be made into cards or other objects.

5. CLEANING UP

Paper fibers can clog your drain, so do *not* throw any left-over pulp into the sink. Instead, recover it! Use the mold to strain the pulp from the water. Cover the drain in the sink with the mold, and pour the remaining pulp over the screen. Remove the pulp from the screen before it's full. Dry the leftover pulp and place it back in your recycling container. ●





PAPER IN P



I AM A COLLECTOR, A PACK RAT.

My house has shelves full of books, cupboards brimming with old board games. Boxes of vintage magazines and antique postcards fill my closets, and my walls are lined with photographs that were taken before I was born.

Most of what I collect is made of paper, what's known in the antique field as *ephemera*. The word is Greek, originally meaning "that which lasts for but a day." Its more modern use is for items without lasting significance, things that were designed to be used once and then discarded. Most paper ephemera functions in just that way; the daily newspaper is thrown into the recycling bin, along with last week's issues of *Newsweek* and *Time*.

That's the first major obstacle in collecting anything that's made of paper: most of it just disappears after it's been used. What's left are the exceptions, the things that were overlooked, or tucked away for one reason or another. Some of those things are fairly common. There are millions of basements and attics with boxes of *National Geographic*, or local newspapers from the November 1963 weekend after President Kennedy was shot.

Other pieces of paper ephemera are a lot more rare—and a lot more valuable. If you were around in 1952 and had a nickel, you could have bought a pack of bubble gum with a baseball card picturing Yankees rookie Mickey Mantle. That same little piece of cardboard, in good condition, sells for more than \$12,000 today.

In good condition. That's the other obstacle to collecting paper ephemera—paper is fragile and easily damaged. Paper has many enemies, and the primary job of a paper collector (after hunting down the

elusive bit of memorabilia) is to keep that treasure from being damaged or destroyed.

Helping Paper Self-Destruct: Air, Light, Heat

Paper's worst enemy may be itself. Any paper will react with the environment and gradually break down. It's a natural, organic process.

Paper reacts with the oxygen in the air, in a process called *oxidation*. Oxidation of the carbohydrates in its cellulose fibers changes the structure of the cellulose molecules, which results in the paper turning yellow or brown, and becoming brittle. The most extreme example of oxidation (and the most permanent damage to a piece of paper ephemera) is when paper catches fire. You can watch it turn from white to pale brown to dark brown to black in a matter of seconds.

Some papers deteriorate a lot faster than others. The cheapest papers, like those used for newspapers, "pulp" magazines, and inexpensive paperback books, are the least permanent. They are made from wood chips that are pulped—pulverized, mixed with liquid, and then chemically processed. Some of the chemicals accelerate oxidation. More expensive papers, often made from cotton or linen, last longer and contain fewer chemicals.

Light is another factor that can hasten the process of oxidation, causing paper to darken and inks to fade. If you've ever left a newspaper or a paperback sitting in the sun for a day or two, you've seen the results of

light damage. (To experiment with the damage that light can create, see "Paper's Moment in the Sun" on page 15.)

All light is potentially damaging to paper, but ultraviolet radiation from sunlight causes the most deterioration. The damaging effects are cumulative, and are influenced by the length and intensity of exposure. A forty-year-old newspaper that's been stored in a trunk will probably show a bit of yellowing; the front page of a newspaper left out in the summer sun for only an hour will be dramatically darker than its inside pages.

Most sources of light also generate heat, which damages paper in a different way. Heat dehydrates the cellulose fibers in paper, causing them to lose resiliency and strength. Paper that has been exposed to heat (as in the environment of most attics) becomes brittle and more fragile. Rather than bending or folding, it breaks. Heat also dries out most adhesives; magazines and books fall apart and pages detach from covers and spines.



ERIL

by Ellen Klages



WHO DUNNIT?

Could it be...

WRETCHED
WATER
DAMAGE?

The best way to protect ephemera from air, light, and heat is to store the paper items carefully. Keep valuable papers in an acid-free box. (More on acid later.) Don't store paper items in an attic or other overheated room, or one with little or no ventilation. Minimize exposure to sunlight, and if you want to display your paper ephemera, do it in a room with incandescent lighting.

Paper Predators

Paper does not like water or dampness. The cellulose fibers in paper are very absorbent, and will suck up any available moisture. Periodic dampness will cause paper fibers to swell, then contract, causing wrinkling or curling. Steady exposure to moisture will cause the fibers to swell, and pages will stick together. If exposed to enough water, the cells will swell so much that they rupture, and the paper will become a soggy, pulpy mass.

In addition, water dissolves some of the chemicals in the paper, which can have a number of bad consequences. The most minor consequence (although annoying and potentially costly in terms of collectible value) is that when paper absorbs water and then dries out again, it becomes irreversibly stained. A more serious problem is that water-based chemical reactions can produce acids.

Acids are corrosive compounds that weaken the bonds of the paper fibers, leaving them brittle and easily broken. Any airborne pollutants, including common household fumes such as paint, cleaning fluids, and cigarette smoke, may increase the severity of the chemical reaction and subsequent damage. Contaminants that might be on a



Exploring Paper

person's hands, like oils, sweat, or perfumes, can also damage fragile paper items, although the results might not be visible for weeks or months.

The third way that moisture can damage paper is by creating an environment that encourages the growth of molds, mildew, and other fungi. The spores of fungi are always present in the air. When air is stagnant and humid, the spores settle on paper. If enough moisture is present, the spores will germinate and begin to digest the carbohydrates, literally eating the paper. Mild fungal damage will stain paper; a severe fungus infestation leaves paper limp as its structure is destroyed. (Fungi will also digest the iron salts used to process some older kinds of paper, leaving reddish-brown spots called *foxing*.)

Paper is a plant product, whether it's made from cotton rags or wood chips, and almost any organism that feeds on plants will make a meal out of paper. Keeping your collectible postcards away from foraging deer is not usually a problem, but many smaller household creatures can wreak havoc on a collection. Insects such as silverfish, termites, and cockroaches will digest the cellulose in paper. Other insects may not actually eat your collection, but they may lay eggs in it, causing staining and other damage. Rodents like mice and rats will shred anything made out of paper to make their nests. They'll also leave droppings, which are acidic and will leave holes or dark spots.

Basements are common places for people to store newspapers, old magazines, or boxes of family photos that haven't made it into an album. But a basement is a terrible place, in terms of preservation. The dampness will cause chemical changes and encourage mildew, and the vermin that tend to live below ground will have a feast. Storage areas should be dry and up off the ground, with good air circulation, if your paper treasures are going to last.

Hurt by the Holder

Even if you keep your collectible papers out of the hot attic and the damp basement, they're still in danger of damage by common, everyday objects. Let's say you've got an old advertisement from a 1925 magazine and you

want to display it in your living room. You carefully tape it to a piece of sturdy cardboard, put it in a nice wood frame, and hang it over the couch, where it's out of direct sunlight. It's safe, right?

Unfortunately, no. You might not notice the damage for a few years, but your lovely collectible ad is deteriorating in at least four different ways.

First of all, never use tape or other adhesives on valuable paper (whether that value is monetary or sentimental). Tape sticks. That's what it's for. But it sticks permanently, and attempts to remove it usually result in the paper ripping or tearing. Rubber cement contains sulfur, which will fade some colored papers and leave brown stains. Any kind of tape will dry out over time, losing its adherence but leaving a sticky brown residue that can damage the paper. Even "removable" adhesive materials such as Post-it™ notes can leave a thin film of residue, which could later attract dust, dirt, or mold spores.

Cardboard may be a sturdy backing, protecting a fragile ad from creasing or tearing, but it's also made cheaply and is highly acidic. Contact with it can accelerate the chemical changes that will damage the paper item. Even storing collectible paper in a cardboard box can be damaging, because over time the cardboard gives off acidic vapors in a process called *acid migration*.

If you want collectible paper to last for a long time in good condition, it should be displayed or stored in "acid-free,"

pH-balanced materials, often called archival materials. In the early 1980s, the federal government and the paper industry established standards



Though it's approximately thirty years older than the catalog on page 13, this magazine cover from 1897 is in much better shape because it's been well cared for. The author had it professionally mounted on acid-free archival mats and protected it behind nonglare ultraviolet glass.

for archival paper, primarily for the use of libraries, museums, and other archives. The Permanent Paper Standard ANSI Z39 was created, which mandated that to be considered "permanent," paper must meet the following requirements:

- Must have a pH level of 7.5 or greater. (Water, which is neutral, has a pH of 7.0. Anything higher than that is considered basic; anything lower, acidic.)
- Must contain an alkaline buffer of calcium carbonate or other alkali (to retard acid migration).
- Must be free of chemical impurities and, optimally, contain cotton or other rag fibers.
- Must be resistant to tears and folding.

A mat of pH-balanced paper will preserve your framed 1925 magazine in two ways. On it will retard oxidation and acid migration. And it will also keep the paper away from the surface of the glass in the frame. When paper or photographs are displayed in a warm room, condensation can occur on the inside of the glass, the same way it does on the inside of a window. If the paper is in direct contact with the glass, mildew and water damage can occur inside the frame.

The "glass" itself should be Plexiglas, which filters out 95 percent of damaging

ultraviolet light. There is glass that's coated to block UV rays, but Plexiglas has the added advantage of being shatter-resistant, so if your frame falls off the wall, broken glass will not tear the paper.

The frame should be made of an inert material like aluminum or stainless steel. A frame made of wood (which is, essentially, unpulped paper) will oxidize over time, giving off acidic compounds that will damage the paper being displayed. Some plastic frames will also give off chemicals that will accelerate paper deterioration.

If you are storing, rather than displaying, paper items, keeping them in pH-balanced boxes or in polyester (Mylar) envelopes and sleeves will prevent most common damage. Transparent Mylar is frequently used by antique-paper dealers because it is stiff enough to prevent creasing or folding, and allows an item to be viewed easily without being handled. Both pH-balanced storage materials and Mylar enclosures—in a variety of standard ephemera sizes (postcard, comic book, paperback, magazine)—are available from companies that deal in archival and conservation products.

Keeping paper safe can obviously be an expensive proposition. A pH-balanced, archival box for storing 8 × 10 photos, for example, costs around fifteen dollars. If you have an extensive collection, or need to store very large items, boxes and sleeves can be a major investment. The extent to which you conform to archival standards for your paper ephemera depends on how serious a collector you are, and how much you value your collection.

I have to confess that I only have a couple of pieces that are archivally framed. One is an 1897 newspaper page, a color lithograph of the Call Building that is quite large, fragile, and rare. I'm careful with the rest of the things that I collect, but they're probably not going to last another millennium. I keep my postcards in plastic sleeves, in a non-cardboard box that's in a well-ventilated room. I try to remember not to put boxes of magazines in the basement (I don't have an attic), although it's tempting, because there's a lot more room down there. And I never take a 1947 paperback to the beach. ●

PAPER'S MOMENT IN THE SUN

Experiment with the dramatic effects of UV rays on different kinds of paper.

What Do I Need?

- ✓ Four squares of paper, each about 4" × 4". Newspaper and construction paper work especially well. You may also want to pick some papers of your own, or mix and match from the following list: an inside page from today's newspaper; dark-colored construction paper; a page from a glossy color magazine, the Sunday comics, or a comic or paperback book; the label from a can of soup; typing (white or colored) or crepe paper; a brown paper bag.
- ✓ A sheet of cardboard or posterboard (at least 10" × 14").
- ✓ Scissors.
- ✓ Sixteen nickels (or quarters, or buttons or other small, opaque objects).
- ✓ Clear tape.
- ✓ Masking tape.
- ✓ Pen or pencil.
- ✓ A bright sunny day.

You'll need to do this activity between 9:00 A.M. and 3:00 P.M. It will take four hours.

What Do I Do?

1. Tape the corners of each of the squares to the piece of cardboard with clear tape. Make sure the squares aren't touching each other.
2. Put the cardboard outside, in a place that will get direct sun for at least four hours—and someplace where the experiment won't be disturbed. (If you need to, use masking tape to secure the cardboard to a table or deck so it won't blow away.)
3. Put one nickel on each of the four squares of paper. Use a pen or pencil to label that nickel 1.
4. One hour later, put another nickel on each square, and label it 2. Don't disturb the first nickel. Continue this step for two more hours, labeling the next nickels 3 and 4.
5. An hour after you've placed nickel 4, take all the nickels off the paper. The circle next to the 1 is the original color of the paper. (On some kinds of paper, the circles will be very noticeable. On others there may be no visible change.)

What do you notice? Which papers have changed in the sun? Has the sun made them darker? Lighter? Are some colors of ink more faded than others? Has the texture of any of the papers changed? (Try folding a piece that has been in the sun and a piece that hasn't, and compare them.)

Going Further

Now that you know what kinds of paper will change in the sun, you can use them to create art. Take a sheet of paper whose sun effects you like, lay it in the sun, and put some objects on top of it to block the light. (You could use leaves, lace doilies, and tools such as a vegetable peeler.) You can add objects or take them away after a few hours for lighter and darker patterns. After four or five hours, take all the objects off and use your sun-printed paper to wrap a present or hang on your wall.

PAPER AIRPLANES

The most amazing thing about a paper airplane is that all you need to make one is a sheet of paper—nothing more. You don't need scissors, glue, tape, or paper clips. A few folds, a couple of adjustments, and you have a superb paper flyer.

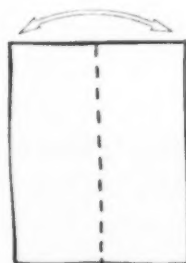
The properties of paper give the airplane all the attributes it needs.

The goal of tossing an airplane is to get it to glide smoothly and gently, flying straight or in a gradual curve. Ken Blackburn, shown here, must have the knack: From 1983 to 1996, he held the Guinness World Record for time aloft for paper airplanes. In 1998, he regained the record with a 27.6-second flight.

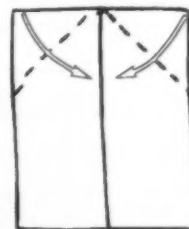


HOW TO FOLD A PAPER AIRPLANE

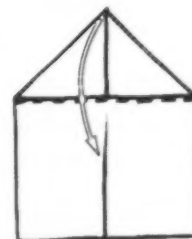
If you've ever made a paper airplane, you've probably just folded the paper into a simple dart—as people have done for at least a hundred years. But in the last two decades, paper airplane designers have imported techniques from origami. Perhaps the best innovation was the addition of one fold to the classic dart design to create a plane called the “Nakamura lock” after the origami artist who designed it.



1 Fold a sheet of paper in half lengthwise. Unfold so that the crease is “valley” side up.



2 Fold the top corners down to the center fold.



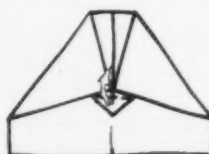
3 Fold the tip down.



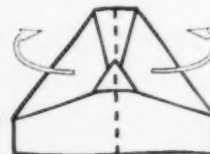
4 Fold about one inch of the tip up; unfold.



5 Fold the top corners down to the center fold so that the corners meet above the fold in the tip. (Note that the top—the nose of the plane—should be blunt.)



6 Fold the tip up. This is the Nakamura lock.



7 Fold the entire plane in half so that the tip is on the outside.



8 Fold the wings down. Trim and fly!



TRIMMING AND FLYING YOUR PLANE

Once you've made all of your folds and the plane looks symmetrical, it's time to *trim* it, or adjust it, for flight. Give it a gentle toss forward. Your goal is to have it glide smoothly and gently to the ground, either flying straight or in a gradual curve.

Make these adjustments, if necessary:

- If the nose drops and the plane dives into the ground, bend up the back of the wings. A little bend goes a long way.

- If the nose rises first and then drops, the plane is stalling. Bend down the back of the wing. Keep your adjustments small.

When you get the plane to balance on the air and float down gently, then you can give it faster tosses.

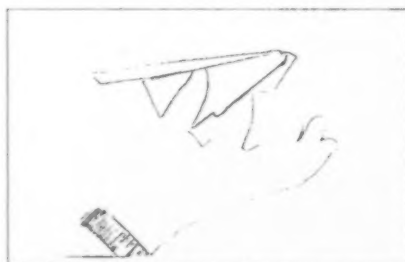
WHAT'S PAPER GOT TO DO WITH IT?

Now that you have a flying plane, you can use it to see the roles that paper plays in its construction.

After the kinetic energy (that is, the energy you put into it by throwing it) of the initial throw has dissipated, paper planes are gliders powered by gravity. As the plane falls, its wings deflect air backward and down, providing thrust and lift. Paper makes a good wing because it's impermeable to air: In a single sheet of paper, multiple layers of interlocked fibers prevent air from flowing through. In contrast, a hole-filled screen from a back door would not make a very good wing.

IT'S A BALANCING ACT

When a paper airplane is aloft, there's a delicate balance between the downward force of gravity on the plane and the upward force of the air. A great insight from physics is that all of the forces of gravity acting on every atom of the plane behave like one force pulling down at a point called the "center of gravity." This point is easy to find. The plane will balance on one finger at its center of gravity (or on two fingers straddling its center of gravity). Mark this point with a pencil.



The forces of the wind on the airplane can also be treated as one force acting through a point called the "center of lift." Get a large fan. Hold the body of the plane loosely between two fingers with the nose of the plane pointing toward the floor. Then move the plane into the blast of air from the fan. There is only one place that you can hold the plane so that it will balance against the wind. Move your fingers along the body of the plane until you find the point at which the plane remains exactly vertical. Mark this point, which is the center of lift. No

matter how thick the airplane is, the air only pushes on the bottom layer, so the shape of the plane controls the center of lift.

So we have gravity pulling down at the center of gravity, and air pushing up at the center of lift. In a properly designed glider, the center of gravity is in front of the center of lift so that the nose of the glider drops. (Check your pencil marks to find out if this is the case for your plane.) The nose slides forward through the air toward the ground, front end first.

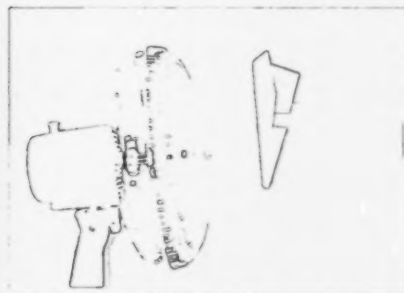
But suppose you have a plane in which the center of gravity isn't in front of the center of lift? One of the great properties of paper is that you can fold it over on itself, creating regions of the plane that are twice or even four times as thick as the single panels of the wings. This allows you to concentrate the weight of the airplane where it helps most, toward the nose. The folds of paper near the front of the airplane move the center of gravity forward. To see how important this is, try flying your plane backward. It won't fly. The plane definitely has a front end.

PAPER'S NOT PERFECT, BUT . . .

The folds that make up an airplane give it the shape it needs, control the distribution of mass, and add stiffness where needed. By itself, a sheet of paper is not very stiff. Hold a sheet of paper by the edge and notice how it droops limply downward. Hold your multifold airplane at the rear center, however, and notice that it doesn't droop. Paper—because it has the ability to hold a fold—can be made rigid. A fold that increases the height of the body of the plane will make a plane that resists drooping under gravity. Small folds at the back edge of the wing or the body allow you to control the flight of the plane. Our plane has been designed so that you can make it fly best by bending up the rear edge of the wing a little bit.

Making a paper airplane—and looking at the properties that paper contains—can give you new respect for the lowly piece of paper, a thin,

lightweight material that's impermeable to air. But the best thing about paper is that it is everywhere, ready to be recycled into airplanes with only a few quick folds. ●



Fragments

by Pearl Tesler

If you're looking for some easy money, bet your friends that they can't fold a piece of paper in half more than nine times. Any size or kind of paper is fine, so long as they fold it evenly in half each time. It may sound simple enough, but they'll be unlikely to make the sixth fold, let alone the ninth. (This trick relies on the mathematics of doubling. To make the ninth fold they'd have to bend 256 pages; that's like trying to fold a book!)

The first commercially packaged toilet paper in America became available in 1857. Sold in packages of 500 individual sheets, the product collected dust on store shelves and soon disappeared. Americans couldn't see why they should spend money on pristine toilet paper when they already had a supply that also provided reading materials: old newspapers and catalogues. Perforated rolls of toilet paper wouldn't catch on until the 1880s, with the advent of indoor plumbing.

"Trust him not with your secrets, who, when left alone in your room, turns over your papers."

—Johann Kaspar Lavater

In 1966, the Scott Paper Company unwittingly altered the course of fashion when it offered paper dresses for \$1.25 by mail order. "Won't last forever . . . who cares? Wear it for kicks—then give it the air." What started as a promotional gimmick became a ripping success; half a million were sold in the first

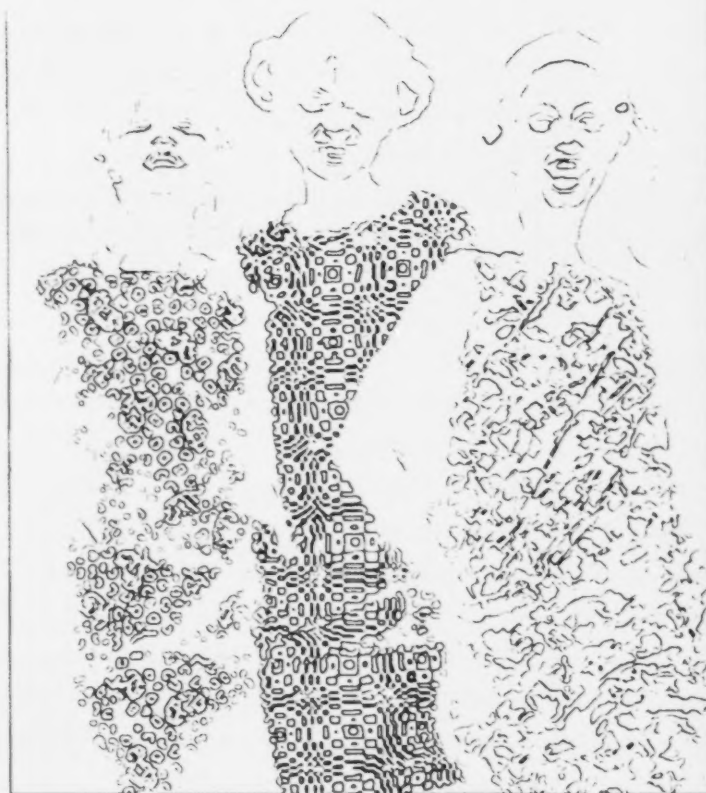
six months. Soon, paper dresses were everywhere in a variety of styles, including \$15 Dior knock-offs. But there were drawbacks. Paper garb offered little warmth in chilly climes. Chafing was sometimes a problem, and inevitably, there were a few fires. Alas, the paper dress fell by the wayside in a few short years, survived only by its crinkly cousin, the hospital gown.

Before papermaking was introduced to the West, monks wrote on parchment made from animal skins. Parchment was so expensive that the monks scoured the ink off unwanted manuscripts and reused the parchment. These recycled texts are called palimpsests.

The highest value paper money ever issued in the United States is the \$100,000 bill, which bears the face of Woodrow Wilson. Don't expect to see one, though. They're only used for transactions between the Federal Reserve and the Treasury Department.

Lignin—the stuff in wood that makes it stiff—is chemically removed from pulped wood in the papermaking process. But lignin isn't altogether a waste product; it's used to make artificial vanilla extract.

Drafted in 1776, the Declaration of Independence is one of our country's most cherished documents. It's also so badly faded that many of the signatures can no longer be read. Archivists attribute the declaration's sad state to rough treatment earlier in the nation's



history, including years of display in a sunlit hallway. Ultraviolet light from the sun excites the molecules in ink and causes them to react with oxygen—or oxidize—and lose their color.

Today, the Declaration of Independence lives under armed guard at the National Archives in Washington, D.C., in a helium-filled case, protected by bulletproof glass and a yellow filter that blocks out ultraviolet light. A three-million-dollar computerized camera watches the document for any signs of further fading. The system is so sensitive, it can detect changes or deterioration invisible to the human eye.

"A verbal agreement isn't worth the paper it's written on."

—Samuel Goldwyn (attributed)

Tracing paper was first made by mistake in the 1930s when an

employee at an English paper mill accidentally added way too much starch to a vat of paper pulp. The thin, semitransparent sheet that resulted proved so useful that the mill soon began mass-producing it.

Take a paper towel and try to make two straight tears in it, one lengthwise and one crosswise. Did you have trouble making one of the tears? Paper towels are formed on a wire screen that creates a grain in the paper. It's easy to tear along this grain, but almost impossible to tear a straight line across it.

At the close of World War II, Japan unleashed a secret weapon: paper balloon bombs. Launched into the prevailing winds that carried them to the United States mainland, the thirty-foot balloons were intended to explode on contact, causing widespread fires and panic

that would divert resources from the American war effort. Some nine thousand of the balloon bombs were launched from Japan. Fewer than a thousand reached North America, some landing as far inland as Michigan. Most failed to detonate or landed in remote areas where they did no harm. The only balloon bomb to cause casualties was discovered by a group of children on a picnic in Oregon in 1945. When one child touched the shiny object, it detonated and six people were killed.

To keep the Japanese from knowing whether or not their balloon assault was successful, the American government allowed absolutely no coverage of the story. Kept uninformed by the news blackout, Americans spotting the mysterious balloons had no idea what they were; the result was some of the first eyewitness UFO accounts.

There are 500 sheets of paper in a ream, 25 sheets in a quire.

The Paper Chase is a centuries-old English game, also called Hare and Hounds. One person—the hare—runs ahead and sets the trail by scattering small scraps of paper. After giving the hare a good head start, the rest of the players—the hounds—set out after the hare by following the paper trail. When one of the hounds sees evidence of the trail, he or she yells “On, on” to signal to the others that they are on the trail. Today, this game still has a small but ardent worldwide following. In the modern version—called “hashing”—the hare sets the trail with chalk or flour instead of paper.

Every Sunday, half a million trees are used up to provide Ameri-

cans with their Sunday newspapers. The *New York Times* alone consumes enough newsprint each Sunday to equal 118 acres of forest.

Who can resist the invitation to scratch-n-sniff? A flick of the finger and the smell of perfume, pizza, or fabric softener wafts magically into the air. The secret to sealing scent on paper is a process called microencapsulation.

First, oily scent is stirred together with gum arabic. Fast beating turns the mixture into an emulsion, in which tiny blobs of the smelly oil are surrounded and coated by the gum arabic. As the mixture dries, the gum arabic hardens and seals the blobs of scent inside. Adding a little water and glue makes a light paste that's ready to be printed on paper. Then all it takes is a scratching fingernail to break the capsules and release the scent.

Have you ever wondered why we call complicated forms and procedures “red tape?” In England, official documents used to be tied together with important-looking red ribbon, which they called red tape, even though it wasn't sticky. Every time a document was read, the red tape had to be untied and then later retied, an annoying and time-consuming formality.

Fahrenheit 451 is a story written by Ray Bradbury in 1953 about book burning and the evils of censorship. (The title is the combustion temperature of paper.) Apparently missing the point, a middle school in Irvine, California, issued expurgated

copies of the book to students. Complaints from parents and media attention convinced school officials to bring back the uncut version.

Next time you're stuck in the woods without a cooking pot, remember that you can boil water in a paper cup. Paper burns at 451° F (as we learned from Ray Bradbury), but water boils at 212° F. It'll work fine as long as the paper is in contact with the cooler water. But once the water evaporates, watch out!

Here's what you can make from a cord of wood; that is, a stack of wood 4' by 4' by 8':

- 4,384,000 postage stamps
- 90,000 sheets of bond stationery
- 2,700 copies of the average daily paper
- 1,200 copies of *National Geographic* magazine
- 942 one-pound books

Paper or plastic? If you think that paper cups are the clear environmental choice, think again. A Styrofoam cup takes half as much energy to make than a paper cup

and releases 35 percent less toxic chemicals into the environment. Also, Styrofoam can be recycled—waxed paper can't.

One unique trait of genuine U.S. currency is the paper it's printed on. Manufactured exclusively for the government, it's made of a blend of linen and cotton with tiny red and blue fibers embedded in it. It's a federal crime for anyone else to make or possess similar paper.

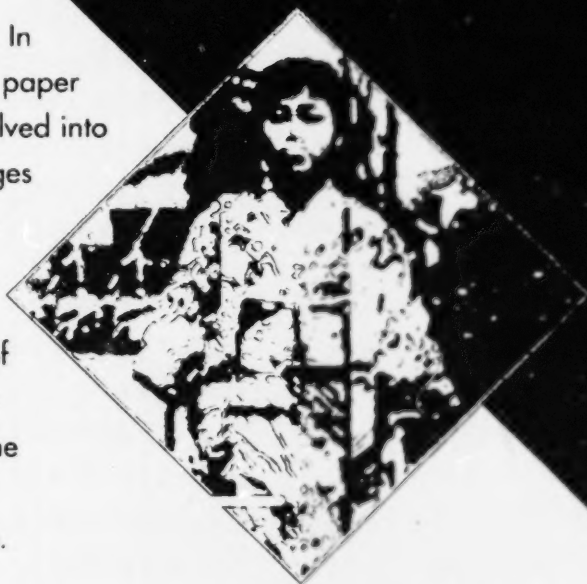
Throwing confetti derives from an older tradition of throwing grains or nuts at newlyweds to transfer the fertility of the seeds to the people being showered with them.

Papercutting is a folk art that is thought to have developed in China in about A.D. 400, not very long after the invention of paper itself. Delicate, intricate pictures are created with a pair of scissors or a knife. Traditionally popular subjects are animals, such as the pandas shown below, Chinese opera masks, and legendary tales. ●



TO AMERICANS,
PAPER FOLDING IS
MOSTLY A CHILD'S
PASTIME.

It's hard to imagine getting through school without making paper dolls, airplanes, sailor hats, or cootie catchers. In Japan, though, paper folding has evolved into an art for all ages called origami, whose beauty and simplicity is reminiscent of other Japanese creations like the bonsai tree or the Zen garden.



EXPLORING

ORIGAMI

by Dana Mackenzie

The art of paper folding, like the art of papermaking, began in China, but it spread to Japan by the sixth century A.D. Over the centuries, it became an integral part of Japanese culture. Paper butterflies symbolized the bride and groom at weddings; folding a thousand paper cranes became a traditional way to ensure a long and healthy life.

In Japan, legend says that a person who makes a thousand origami cranes will live a long life. The legend took on new meaning in 1955, when Sadako Sasaki (shown above), a twelve-year-old girl who was exposed to radiation during the bombing of Hiroshima, contracted leukemia. While in the hospital, she tried to fold 1,000 cranes but died before she could finish.

Sadako's statue now stands in Hiroshima's Peace Memorial Park, where it is decorated every year with thousands of origami cranes, folded by children from around the world, as a symbol of peace.

Animals were an especially popular theme, as "folders" developed more and more ingenious ways to make a little diamond of folded paper sprout legs or wings—and even to make it float, hop, or fly. Even so, Japanese origami evolved very slowly. According to American origami expert Peter Engel, Japanese folders invented about 150 traditional origami figures in a millennium of folding.

But in the last twenty-five years, new materials, new methods, and new ideas have transformed the traditional world of origami on both sides of the Pacific. The simple and stylized animals of the past, which relied as much on the viewer's imagination as on the folder's

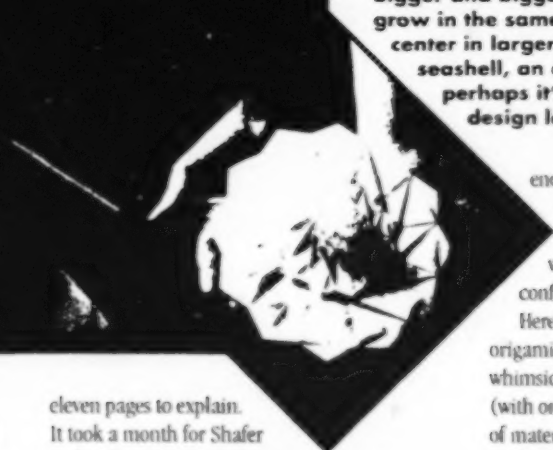




FLOWER TOWER

by Christopher Palmer

In tessellations, the same folding motif is repeated over and over at the same size. In his "flower tower," Palmer repeats a design in bigger and bigger scales. Many things in nature grow in the same way, spiraling out from the center in larger and larger layers—think of a seashell, an artichoke, or a sunflower. So perhaps it's no accident that this abstract design looks almost as if it were alive.



enough to allow each designer his own style and philosophy. Just as no musician will ever confuse a Beethoven symphony with a Mozart, no origamist will ever confuse a Shafer model with a Lang.

Here is a sampler of the creations of modern origamists, ranging from the gorgeous to the whimsical. Just remember, every one of these (with one exception) began as a single sheet of material, and can be folded without cutting or gluing.

INTERLOCKING CUBES

folded by Laura Mappin,
after Tomoko Fuse

The Japanese have never been quite as fussy about using just one piece of paper as American and British folders. In one of the most striking branches of origami, called modular origami, many identical, interlocking units fit together to form a complex model. (Each of the cubes to the left is made from twelve identical parts; the different sizes of the cubes come from the different sizes of the original paper squares.) The units themselves are not very interesting to fold, but the thrill of modular origami is assembling the units.

The best designs have ingenious systems

skill, have been joined by bugs and beasts bristling with anatomically correct legs and teeth. Some folders are exploring new subject matter, such as elaborate cuckoo clocks or working Swiss army knives. Others venture into the abstract world of mathematics, assembling spectacular interlocking polyhedra or tile mosaics, or defying straight-line geometry to sculpt graceful curves. As origamists reach out to new materials (silk, transparency film, bubblegum wrappers) and new design tools (yes, the computer age has arrived), perhaps only two things remain taboo to serious folders: scissors and glue.

"Cutting is the least aesthetic folding operation of all because it destroys the wholeness of the paper," writes Jeremy Shafer, the dynamic origamist/juggler/unicyclist who leads San Francisco's origami club, the Bay Area Rapid Folders (BARF). "I like to think of the origami paper as sacred, and from this viewpoint, I see the cutting of origami as sacrilege." Or, as Eric Erös, another BARF member, says, "Scissors make it too easy."

The new origami is anything but easy. Shafer has designed a model of the Star Trek spaceship *Enterprise* that takes seventy-two diagrams and

eleven pages to explain.

It took a month for Shafer to design, and the average folder could expect to take a week to make it. Origami designer Robert Lang routinely stretches the limits of belief with critters like his computer-designed lobster, which comes fully equipped with eight legs, a tail, a head, claws, and antennae (see page 23).

To origamists, their burgeoning art form is like music. Most folders begin as performers, bringing to life the work of the composers, but a restless few feel the urge to explore further. As Shafer says, "We have to come up with ideas that extend the bounds of origami, not the mounds of paper." These few—Americans like Shafer, Lang, John Montroll, and contemporary Japanese folders including Toshikazu Kawasaki and Jun Maekawa—vie to create spectacular new compositions. Yet the art is large



Expl

of pockets and tabs that lock the whole contraption together without glue and give it astonishing strength for a paper figure.

Though modular origami dates back hundreds of years, a folder named Mitsunobu Sonobe invented the locking mechanism that has made it popular. Variants of his unit, as well as completely new designs, are being invented all the time.

OPENBACK TWIST OCTAGONS

by Christopher Palmer

This study in symmetry, an origami tessellation, was folded by Chris Palmer, a San Francisco native who now lives in Maryland. When lit from behind, different parts of the design are lighter or darker depending on the number of layers of paper the light has to pass through. When lit from the front, the internal structure becomes invisible, and the model looks completely different. Palmer takes his inspiration from the mosaic designs of

Arab mosques, such as the famous Alhambra in Granada, Spain. In these patterns, called tilings or tessellations, a small number of shapes are repeated over and over to fill up a planar region. Most tessellations are not only mirror-

symmetric, but have a variety of rotational symmetries. Turn this one around by ninety degrees, and it looks just the same as before. Palmer has developed a method for converting any tiling with regular polygons—triangles, squares, hexagons, and the like—into an origami pattern. In theory, the pattern can be repeated forever. In real life, an origamist is limited only by the size of his paper and his patience. As you can see, Palmer is very patient!

FLASHER HAT

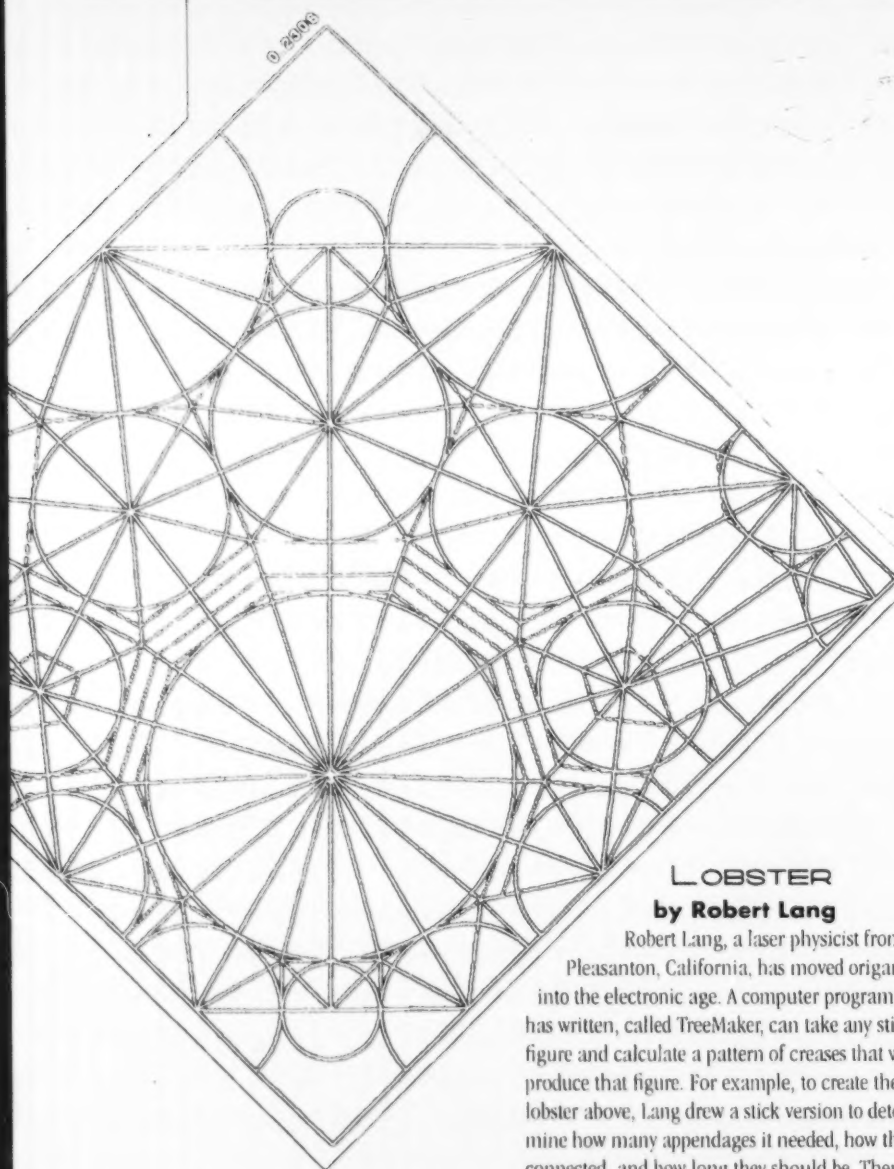
by Jeremy Shafer

After you've seen a few Shafer models, you learn to expect the unexpected. There's the Swiss army knife that opens and closes (and, Shafer promises, really can cut . . . a cobweb). The flyswatter that turns over to reveal a squashed man on the other side. The envelope that opens to reveal a pop-up dragon.

One of Shafer's signature pieces is the "flasher." The flasher hat below folds up instantly to a cylinder no bigger than a roll of toilet paper. In fact, some of Shafer's flashers fold up by themselves if you let go of them.

According to Shafer, he designed the first flasher with Christopher Palmer, after Palmer saw a rose by a legendary Japanese origamist, Toshikazu Kawasaki. The two realized they could use Kawasaki's system of pleats to make a model that could grow or shrink. Shafer estimates that he has designed about thirty-five different flashers, and he even owes his college degree to them. As a student at the University of California at Santa Cruz, he majored in mathematics because "it was the most origami-like of the majors," and he presented a senior seminar on

BEST COPY AVAILABLE



LOBSTER by Robert Lang

Robert Lang, a laser physicist from Pleasanton, California, has moved origami into the electronic age. A computer program he has written, called TreeMaker, can take any stick figure and calculate a pattern of creases that will produce that figure. For example, to create the lobster above, Lang drew a stick version to determine how many appendages it needed, how they connected, and how long they should be. Then he gave the information to TreeMaker, which printed out this folding pattern.

If you fold along the lines the right way, you get a primitive lobster model with flaps of paper that correspond to each limb of the stick figure. From there, Lang says, he uses his origami experience—not the computer—to transform the flaps into claws that look as if they might pinch you if you get too close. "After a while, you learn the repertoire of how you put in elbows or feet," Lang says. "The hard part is getting the flaps in the right places to begin with."

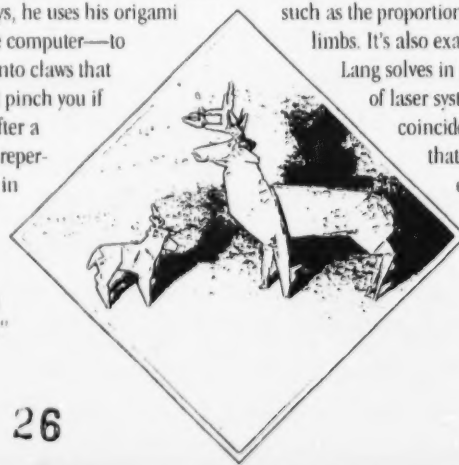
flashers. Even his professors were baffled, Shafer recalls. "I taught them how to fold a flasher," Shafer says. "I was practically having to fold it for them, because they had the instructions in front of them but they couldn't follow them. That was quite a turnaround, you know—you have all those geniuses, and they can't even fold the basic flasher!"

The lobster (top right) and the larger of the two deers (at right) are complex creatures that were both designed by Robert Lang using TreeMaker, the software he developed. TreeMaker can calculate a pattern of creases (the lobster pattern is shown above).



The secret of TreeMaker lies in the circles that have been drawn on the crease pattern. Each circle corresponds to one appendage. For example, the gigantic circle eventually turns into the lobster's tail. Inside each circle, the creases fan outward like the spokes of an umbrella. When collapsed, each of these "umbrellas" becomes a narrow, straight projection or flap, which Lang subsequently shapes into the appendage of choice. The computer packs the circles together as tightly as possible (to avoid wasting paper), while respecting the overall geometry of the lobster.

This type of mathematical problem is called "constrained optimization"—finding the optimum design that satisfies certain constraints, such as the proportionality of the lobster's limbs. It's also exactly the type of problem Lang solves in his day job as a designer of laser systems. "Is it just lucky coincidence," Lang asks, "or is it that to a man with a hammer, everything looks like a nail?" ●

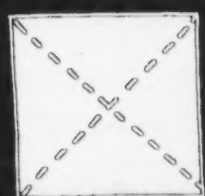


Try This!

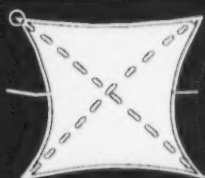
FLAPPING BIRD

THIS MODEL, DESIGNED BY SAMUEL RANDLETT, SEEMS TIME BUT IT'S ONLY THIRTY YEARS OLD!

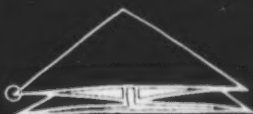
Please note: If you've never done origami before, it takes you about a half hour to fold. The results are v



1. Fold a square piece of origami paper along one diagonal, colored side out. Then, unfold and fold along the other diagonal



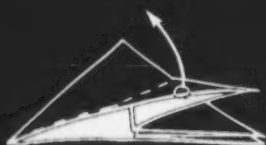
2. Push in from opposite sides until you create four equal-sized triangles



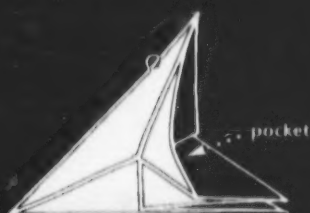
3. Move one flap (half of the top triangle) from the left to the right.



4. Fold the left side of triangle down so that it is along the triangle's bottom then unfold.



5. Now comes the trickiest step. Take just one layer from the bottom side of the triangle and fold it back up to the left side along the crease you just made. This exposes the uncolored (or reverse) side of your paper and it also creates a pocket on the right.

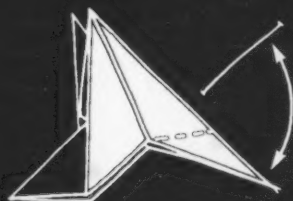


Stick your finger in that pocket. Keep flattening out the long edge you just folded until it lies straight. In the process, the pocket on the right will close over your finger and you'll create a new crease.

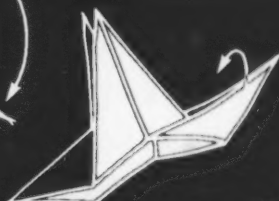
Flatten the folds. You've just made one wing of the bird.



6. Turn the model over and create other wing in the same way.



7. Fold the long, narrow point (which will become the neck and head) up and out to the side so that the top of the neck is in line with the bottom of the body, then unfold.



8. The bottom of the body forms a pocket. Open this pocket up wide and turn the neck inside out along the same crease you just made, then flatten again.



9. Finally, to make the head, fold the end of the neck down and unfold. (You can judge by eye how big you want the head to be and what angle you want it to make.) Then open the neck up at the top and turn this last fold inside out.



The bird should look like the one in this photo. If you hold it by the neck and pull the tail, you can make it flap its wings!

Ask Us

by Michael Matz

How does a chameleon process the surrounding color?

—Maria Bartelt
Ames, Iowa

Chameleons change color and often match their surrounding color, camouflaging themselves as a result. But chameleons don't change color *in response* to the color of their environment. Instead, factors such as variations in temperature and sunlight, along with the chameleon's emotional state, are responsible for the alterations in skin hue. Some dramatic color changes, such as those that take place during the acts of courting and defending territory, may actually make the lizard more conspicuous.

Chameleons—a family of Old World lizard species found primarily in Madagascar and mainland Africa—have the amazing ability to change their skin color in just minutes. Depending on the situation and the species, chameleons can display an impressive variety of colors and patterns of colors, including green, red, blue, black, brown, and yellow. For example, the lips of a male Jackson's chameleon may turn yellow when it tries to impress a female. Other lizards not in the chameleon family, including the deceptively dubbed American chameleon, also have color-changing abilities.

Biologists believe that the chameleon's color wizardry is caused by several layers of special color cells. Probably the main drivers of color change are cells deep in the skin called *melanophores*. Melanophores contain the dark brown pigment melanin, the same substance that causes tanning in humans. These cells also have tentacle-like arms that snake toward the skin surface through other special color cells, including cells with yellow and red pigments and cells with light-bending crystals.

Melanophores can either keep the dark pigment in their cell centers or they can disperse it through their arms into the other cell layers, hiding one or more of the other colors. An angry chameleon, for instance, grows darker by sending melanin toward the skin surface, blocking other color cells. The red and yellow color cells can grow bigger or smaller, adding to the remarkable variety of possible color patterns. If the cells containing yellow pigment expand over light-bending cells that emit blue light, the chameleon will turn green.

The chameleon needs its color skills for survival. It may turn dark on chilly mornings to absorb more sunlight, which will help it stay warm. And it uses flashy color changes to scare away predators. Contrary to legend, the chameleon would not be able to turn plaid on a tartan blanket to camouflage itself from a hungry opponent.

Why haven't we ever seen predictions of what our descendants of, say, one million years from now might look like? Might we evolve similar to the classic alien profile?

—jmw@jmw.mv.com

There are actually many theories about the future evolution of humankind, and they run the gamut from human robots to E.T.-like creatures to the same old people that are around today.

Some scientists believe that advances in genetic engineering and robotic science will give people the power to control their evolution. Hans Moravec of Carnegie-Mellon's Robotics Institute predicts that "surgeons" will transfer human brain functions to robots and merge human and machine into one. Another vision of a genetically altered human is one of a being that can incorporate plant cells into its body, so it can gather energy from the sun through photosynthesis.

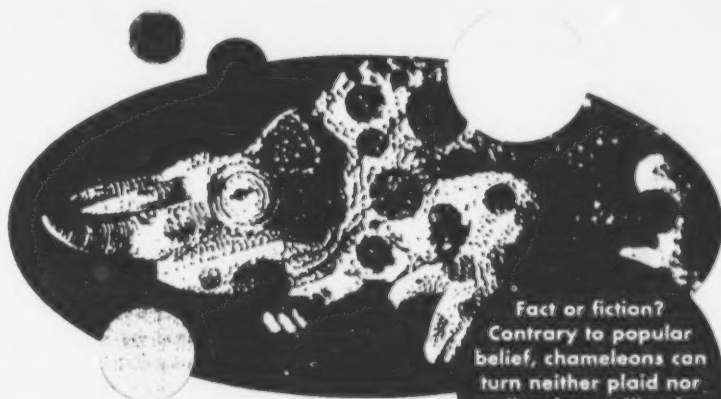
Other predictions envision human beings in the classic alien form—superintelligent, with a huge brain. Scottish paleontologist Dougal Dixon believes that people millions of years hence will have shriveled bodies and paralyzed legs, but enlarged brains that are ten times heavier than the rest of their bodies. How would this E.T.-like figure evolve? According to Dixon, medical science would be to blame. Modern medicine, by allowing people with debilitating diseases to survive and pass down their genes,

will eventually leave everyone diseased, with organs and muscles withered. To survive, we will use technology and the powerful intelligence of our inflated brains to genetically engineer a synthetic body that will encase our real body from the moment of birth.

But many evolutionary biologists hold a radically different opinion: The "big brain—little body" vision, they contend, is based on the faulty assumption that the brain will grow in the future because it has grown in the past. Biologists have found that the ratio of brain to body size—which expanded rapidly beginning about half a million years ago—peaked within the last thirty thousand years and has not changed since. In addition, head size will always be limited by the size of a woman's pelvis, which must allow a baby's head to pass through during childbirth.

Scientists also question the small body of Dixon's vision. According to Baltimore gerontologist Richard Cutler, larger brains would need more energy, so people would have to evolve larger bodies to supply that energy. Anthropologist C. Owen Lovejoy of Kent State University points out that if human beings had access to advanced genetic engineering, we would not let our bodies wither away; instead, we would be able to make the human body stronger, less diseased, and longer lasting.

Actually, many biologists doubt the possibility of any body changes. By looking at fossil records of different species, they have shown that little anatomical change occurs when species don't split into new species—something that happens when populations are isolated and can't reproduce with one another for very long periods of time. The chance of this happening with humans is very small, biologists say. That is, unless a population of humans started a colony far away in outer space! ●



Fact or fiction?
Contrary to popular belief, chameleons can turn neither plaid nor polka dot—unlike the fantasy illustration shown here.

Recycled Paper

THE MEDIUM IS THE MESSAGE

What's This Magazine Printed on, Anyway?

You've probably noticed that we've used two types of paper in this issue.

Try flipping through the magazine and notice the differences between the two. This different look was made possible through the generosity of New Leaf Paper and Fraser Papers, who provided paper stock for this issue.

At the Exploratorium and elsewhere, choosing a paper for a publication is an important part of a graphic designer's job. There are a lot of factors to consider: different colors and finishes can be used to create a mood, for example, and some papers will be better than others for the particular illustrations or photographs involved in a publication. Designers must stay in budget and worry about the environmental impact of their paper choices as well. This magazine can show you some of what designers watch for.

The white stock in this magazine, manufactured by New Leaf Paper, is called Reincarnation Matte. It's 100 percent recycled eighty-pound text, 50 percent of which is post-consumer waste (that is, deinked fiber from recycled paper collected from homes and offices), and it's processed without chlorine. You'll notice that this paper has a coating. The coating provides a delicate shine that enhances the images; at the

same time it's nonreflective, which makes the text comfortable to read.

The ivory stock, called Synergy, from Fraser Papers, is from a high-quality text and cover grade line that is archival, acid free, and contains a minimum of 50 percent recycled fiber, including 30 percent post-consumer waste. This paper is uncoated, so it's not shiny at all. Synergy is designed for excellent process color printing.

Look at the photographs on these two pages, and notice the differences in the way they look on the coated and uncoated papers. Next, check out the effects of using different colors of paper. Notice that the same ink colors are used throughout the magazine, but they don't look quite the same on the ivory paper as on the white.

The magazine offers just two examples of a growing number of environmentally sound papers that can meet a variety of needs. In fact, according to Jeff Mendelsohn of New Leaf Paper, "papers with post-consumer content that have

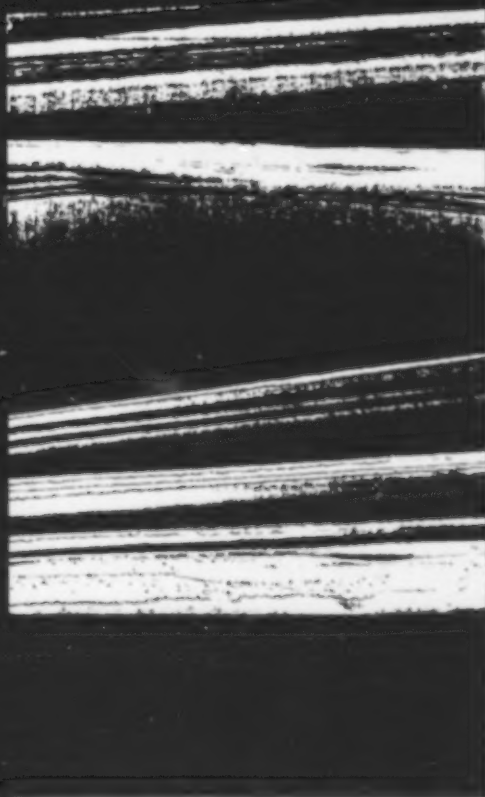
been bleached without chlorine are available for almost any project: annual reports, direct mail, sales collateral, publications, corporate identity—you name it!"

Dick Clapp of Fraser Papers explains that the use of recycled fibers in high-quality printing and writing papers has increased dramatically over the past ten years. The primary issues facing manufacturers were the availability of processes to give clean, bright fibers, and the ability to manufacture high-performing papers using these recycled fibers. These issues have been resolved.

What Exactly Is Recycled Paper?

The Environmental Protection Agency guidelines stipulate that uncoated papers manufactured for printing and writing purposes contain a minimum of 30 percent post-consumer content, and that coated papers contain at least 10 percent post-consumer content. But that means paper containing 90 percent virgin fiber can be labeled "recycled"! At the other end of the spectrum are papers that contain 100 percent post-

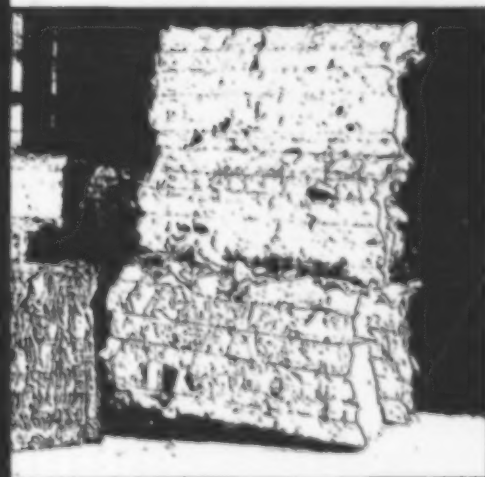




consumer content. Clapp notes that high-quality paper grades from 100 percent post-consumer waste are now available from several manufacturers. Examples of such a grade are Fraser's Genesis and Eco-Offset from New Leaf Paper. In addition, there is a wide choice of papers containing between 30 percent and 100 percent post-consumer content.

The Benefits of Recycled Paper

Recycling paper saves our forests, of course, but there are many additional benefits. First of all, we keep paper out of the landfills. At the



Exploring Paper

Recycling Terms for the Savvy Consumer

Post-consumer waste: All the paper we discard at home and at the office. By recycling it, we keep it out of our overburdened landfills.

Pre-consumer waste: Includes waste from printing companies as well as unsold magazines and newspapers.

Nonwood fiber paper: Paper made from agricultural by-products such as banana stems and corn stalks, or from plants such as kenaf, a member of the hibiscus family, and hemp.

Virgin fiber: Fiber from trees or other sources that hasn't been used to make paper or any other product.

Deinking: A process that removes ink and other materials such as coatings from recycled paper.

Processed chlorine free: Recycled paper that's unbleached or bleached without chlorine or chlorine derivatives. Chlorine bleaching creates toxins such as dioxin, which contaminates rivers and groundwater, and has adverse effects on both wildlife and people.

Totally chlorine free: Virgin fiber paper that's unbleached or bleached without chlorine or chlorine-based chemicals.

Elemental chlorine free: Paper that's processed without elemental chlorine, although chlorine derivatives such as chlorine dioxide are used. Such processing reduces the formation of dioxin, but still produces other toxic chlorine compounds.

present time, 40 percent of the material in landfills consists of discarded paper products. And because waste paper needs less processing than virgin wood pulp, there's a large energy savings. There's also a huge reduction in air pollution.

Recycled paper of the quality that can be used for printing or writing does undergo a number of steps, however. Generally the waste paper is washed to remove ink and coatings and then bleached. Bleaching processes that involve chlorine produce highly toxic by-products and create serious environmental hazards. But other bleaching techniques are available. Jeff Mendelsohn explains the alternative used by New Leaf Papers: "Most New Leaf Paper products are bleached with hydrogen peroxide (H_2O_2)—the same stuff that people use to bleach their hair. When used to bleach deinked paper pulp, hydrogen peroxide breaks down to benign elements—water and oxygen."

What Will the Future Bring?

Mendelsohn notes that "in some respects, the future is now. There are truly environmentally sound products on the market that are cost competitive. Going forward, we are excited about new product developments using sustainably

forested wood fiber, and products using agricultural by-products as fiber source." Dick Clapp agrees, explaining that using agricultural by-products (for example, stalks of corn, wheat, and straw) makes environmental sense "because otherwise these waste stalks are burned, contributing to air pollution. Clapp also points out that forests—particularly young forests—have a positive effect on greenhouse gases through their use of carbon dioxide in photosynthesis.

But the situation for U.S. paper manufacturers is not entirely rosy. According to Clapp, domestic paper manufacturers face financial competition from South American and Southeast Asian companies with poor environmental records. This particularly puts pressure on the smaller mills in the United States that traditionally have produced a wide variety of high-quality recycled papers.

So what does the paper buyer who's interested in the environment need to know? "The purchaser needs to understand exactly what type of paper specifications they want, get to know their suppliers, and demand the products they desire," says Clapp. "Paper manufacturers listen to their best customers." ●

Tools & Toys

When I was in first grade, I was fascinated by all the different kinds of paper Miss Kellman could produce for activities. Her supply closet was full of thick, colorful construction paper for crafts, big sheets of bright white butcher paper for murals, and soft beige sheets of newsprint with pale green lines to guide our wiggly printed letters.

To decorate the classroom, we made flowers and pilgrim hats and Christmas trees by folding and cutting construction paper. If only we'd had *Origami* by Steve and Megumi Biddle (\$22.00). This beautifully illustrated book contains colorful woodblock prints of the Japanese masters in the collection of the Metropolitan Museum of Art. Inspired by these artworks, the Biddles, who are origami experts, created birds, flowers, and animals that you can fold from the origami paper included with the book. Text contains commentary about the art as well as detailed, well-illustrated instructions for making more than thirty different pieces of origami art.

The kids in my class would have gone nuts for *Folds in Flight Origami* (\$6.90). The step-by-step illustrated instructions show you how to make five different paper airplanes—including the Lightning Bolt Jet, the Super Loop-de-Looper, and the Aerial Acrobat. The kit comes with enough unusual, patterned origami paper to fold thirty great-looking planes (check out the blue paper with the yellow lightning bolts!). A cardboard runway (complete with a pop-up control tower) gives you a convenient place for your jets to land. (To learn more about origami, see "Exploring Origami" on page 20.)

For the more advanced paper pilot, I recommend *Kid Kits: Paper Planes* (\$9.95). This kit contains everything you need to make five different, unusual paper airplanes. The designs for the planes are printed on heavy, coated paper. All you have to do is cut, fold, and glue, guided by the illustrated, sixteen-page instruction booklet. The kit even includes a sheet of heavy plastic for you to cut on. Stickers with Air Force insignias, flames, stars, and numbers allow you to personalize your planes. These planes are so real looking, the kit comes with a pilot's license!

Or check out *White Wings: Excellent Paper Airplanes* (\$19.50). With this kit you can make fifteen different gliders, designed by the Grand Prize winner in the First International Paper Airplane contest. You've never seen paper airplanes quite like this! The kit includes a sixty-eight-page instruction booklet, with directions for assembly, and tips on how to fly your gliders. It even has a rubber band catapult to launch your planes far into the wild blue yonder. (To learn more



about paper airplanes, see "Try This" on page 16.)

Sorry, Miss Kellman. Construction paper just isn't as exciting these days.

—Betsy McGee

All of these books and kits are available from the Exploratorium Store, where you can shop in person or order by phone at (415) 561-0393. Also, check out the Exploratorium Store online, which offers a large assortment of products, at www.exploratorium.edu/store. Exploratorium Members get a 15 percent discount. For membership information, call (415) 561-0302. Prices and availability subject to change.

Related Reading

Pulp Nonfiction by Jolie Velazquez

The Art & Craft of Handmade Paper by Vance Studley. New York: Van Nostrand Reinhold Company, 1977. Provides a short history of papermaking and a well-organized introduction to making paper as a hobby, with many useful illustrations and photos.

Papermaking: The History and Technique of an Ancient Craft by Dard Hunter. New York: Dover Publications, Inc., 1943. This is the major work on the history of papermaking. Hunter was the first historian to concentrate on this subject and his books and articles are still widely cited.

Handmade Paper by Karen Mendelow

Make It with Paper by Paul Jackson and Vivien Frank. London: Quintet Publishing Limited, 1992. This informative book teaches you everything from how to make paper to how to make wonderful things with it. It includes a large section on origami, and covers both eastern and western designs.

Paper Airplanes by Paul Doherty

The Best Paper Airplanes You'll Ever Fly by the Editors of Klutz. Palo Alto: Klutz Press, 1998. A laminated guide with instructions for folding, trimming, and flying three paper airplanes. These planes are made only of paper—no tape, paper clips, or scissors needed.

Return to the Fold by John M. Collins, Don Garwood, and Thay Yang. New York: McGraw Hill, 1995. A book full of clear instructions on how to fold great paper planes, including planes based on the waterbomb origami fold. Also included is a short history of paper airplanes.

Exploring Origami by Dana Mackenzie

If you're interested in joining a local origami group, check out the League of Intrepid Paper Sculptors (LIPS). They meet regularly in Sunnyvale, CA. For more information about the organization and its meeting schedule—as well as related links—visit their Web site at <http://www.aimnet.com/~andalar/origami.html>. Also, visit the Bay Area Rapid Folders (BARF) homepage at <http://www.krmusic.com/barf.html>

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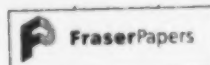
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